Boojum RESEARCH LIMITED

ACID GENERATION AND INORGANIC PRECIPITATE FORMATION IN MINE TAILINGS AT THE SOUTH BAY SITE

FINAL REPORT

BY: R.O. van Everdingen
Margarete Kalin, BOOJUM RESEARCH

Work on the project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada.

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SUMMARY

This study addresses the geochemical dynamics of acid generation based on data generated during the implementation of Ecological Engineering for tailings ares generated by copper /zinc mine.

The total quantity of tailings in the South Bay (Northern Ontario) tailings basin is estimated at 760,000 short tons, covering an area of about 200,000 m^2, with thickness of the tailings ranging from 0 to 4.8 m. The tailings were reported to consist of 41.1% pyrite, 4.1% pyrrhotite, 0.63% sphalerite, and 0.14% chalcopyrite, with the remainder consisting of silicates and about 1.0% calcite.

Available data on: topography of the tailings basin, borehole logs, subsurface temperatures, groundwater levels, and chemical analyses of water samples collected from piezometers. Meteorological data were available for Ear Falls, the nearest weather station, 65 km southwest of the study site. Recharge to the subsurface water in the tailings basin is somewhere between 175 and 275 mm per annum.

During the study period from 15 October 1986 to 15 October 1989, water levels in piezometers in the tailings basin have been measured at intervals ranging from less than a week to as much as 11 months. Information on late-winter lows and early-spring highs

in the water levels is available only for 1987. Correlation between water levels and summer-rainfall data for Ear Falls is best sketchy.

Due to the seasonal variations in water levels, the thickness of **unsaturated tailings** varied, with maximum values ranging from 0.67 to 3.53 m, and minimum values ranging from 0 to 2.68 m, for individual piezometer locations.

Available data on **subsurface temperatures** show that temperatures fell below 0°C only in the upper 30 cm in the tailings basin, which reportedly consist of "inert" fill cover. The tailings thus appear not to have been affected by freezing. Moreover, freezing points calculated for water samples from the tailings basin range from -0.05 to -1.52°C.

Water samples for chemical analysis have been collected from most of the piezometers several times during the study period. Although values of [Fe] for a number of samples taken in July 1987 and April 1988 were found to be erroneous, the remaining data clearly reflect the occurrence of oxidation of sulfide minerals in the tailings basin. Sulfate concentrations range from 36.0 to 20,180 $mg.L^{-1}$; iron concentrations from 0.36 to 9938 $mg.L^{-1}$; and zinc concentrations from 0.33 to 1123 $mg.L^{-1}$. These large ranges indicate, that acid

generation is a process which is highly influenced by specific local conditions in the tailings pile.

The results of the chemical analyses suggest that some of the initial Fe content is subsequently precipitated in the tailings pile (and possibly in the underlying sediments), probably in the form of iron-hydroxide and some Na-jarosite, and that some of the initial sulfate is lost from solution by precipitation of gypsum (approximate saturation degrees for gypsum range from -3.27 to +0.47). Minor amounts of sulfate may be converted to H_2S by bacterial action. The chemical analyses further suggest that other elements such as Zn are co-precipitated with Fe.

Using the available chemical analyses and the estimated amount of annual recharge at the site, apparent **sulfide-oxidation rates** have been calculated; they range from 0.0001 to 0.0117 $mol.kg^{-1}.yr^{-1}$ (overall average 0.0031 $mol.kg^{-1}.yr^{-1}$). Calculated apparent **iron-precipitation rates** range from 0.000009 to 0.00092 $mol.kg^{-1}.yr^{-1}$ (overall average 0.00024 $mol.kg^{-1}.yr^{-1}$). These rates are dependent on the thickness of the unsaturated tailings layer and the recharge rates of the tailings basin.

RÉSUMÉ

Cette étude porte sur les dynamiques géochimiques de la création d'acide, selon les données créées pendant l'implantation de l'ingénierie écologique pour les ares de déchets, provoqués par la mine de cuivre et de zinc.

La quantité totale de déchets se trouvant dans le bassin de déchets de South Bay (au Nord de l'Ontario) est estimée à 760 000 tonnes courtes, recouvrant une surface d'environ 200 000 m², avec une épaisseur de déchets allant de 0 à 4,8 m. Les déchets consisteraient en 41,1 % de pyrite, 4,1 % de pyrrhotine, 0,63 % de sphalérite, et 0,14 % de chalcopyrite, le reste étant composé de silicates et d'environ 1 % de calcite.

Des données sont disponibles sur : la topographie du bassin de déchets, les diagraphies de sondages, les températures souterraines, les niveaux d'eau souterraine, et les analyses chimiques des échantillons d'eau recueillis par les piézomètres. Des données météorologiques étaient disponibles pour Ear Falls, la station météorologique la plus proche, 65 km au sud-ouest du lieu de l'étude. La recharge de l'eau souterraine dans le bassin de déchets se situe entre 175 et 275 mm par année. Pendant la période de l'étude, du 15 octobre 1986 au 15 octobre 1989, les niveaux d'eau dans les piézomètres du bassin de déchets ont été mesurés à des intervalles allant d'un peu moins d'une semaine à 11 mois. Des informations sur les niveaux bas d'eau de la fin de l'hiver et sur les niveaux élevés d'eau du début du printemps ne sont disponibles que pour 1987. La corrélation entre les données sur les niveaux d'eau et celles sur les pluies d'été pour Ear Falls est au mieux superficielle.

À cause des variations saisonnières dans les niveaux d'eau, l'épaisseur des déchets non saturés a varié, avec des valeurs maximales allant de 0,67 à 3,53 m, et des valeurs minimales allant de 0 à 2,68 m, pour des emplacements particuliers de piézomètre.

Des données disponibles sur les températures souterraines montrent que les températures tombent au-dessous de 0xC seulement dans les 30 cm supérieurs du bassin de déchets, qui consisteraient en une couverture de remblaiement inerte. Les déchets, par conséquent, n'apparaissent pas avoir été affectés par la congélation. De plus, les points de congélation calculés pour les échantillons d'eau provenant du bassin de déchets vont de 0,05 à -1,52xC.

Les échantillons d'eau pour l'analyse chimique ont été recueillis de la plupart des piézomètres plusieurs fois pendant la période de l'étude. Bien que les valeurs de [Fe] pour un nombre d'échantillons pris en juillet 1987 et en avril 1988 s'avérèrent erronées, le reste des données reflète clairement l'existence d'oxydation des minéraux sulfurés dans le bassin de déchets. Les concentrations de sulfate vont de 36,0 à 20 180 mg.L-1; les concentrations de fer vont de 0,36 à 9 938 mg.L-1; et les concentrations de zinc vont de 0,33 à 1 123 mg.L-1. Ces larges éventails indiquent que la production d'acide est un processus qui est fortement influencé par des conditions spécifiques locales dans le tas de déchets.

Les résultats des analyses chimiques suggèrent qu'une partie du contenu initial Fe est, par la suite, précipitée dans le tas de déchets (et probablement dans les sédiments sous-jacents), vraisemblablement sous la forme d'hydroxyde de fer et un peu de Na-jarosite, et qu'un peu de sulfate initial est perdu de la solution, par précipitation de gypse (les degrés approximatifs de saturation pour le gypse vont de -3,27 à +0,47). De petites quantités de sulfate peuvent être transformées en H2S par l'action bactérienne. Les analyses chimiques suggèrent encore que d'autres éléments, tels que Zn, sont co-précipités avec Fe.

En utilisant les analyses chimiques disponibles et la quantité estimée de recharge annuelle à l'emplacement, les taux d'oxydation de sulfure ont été calculés. Ils vont de 0,0001 à 0,0117 mol.kg-1.an-1 (moyenne totale 0,0031 mol.kg-1.an-1). Les taux calculés de précipitation de fer vont de 0,000009 à 0,00092 mol.kg-1.an-1 (moyenne totale 0,00024 mol.kg-1.an-1). Ces taux dépendent de l'épaisseur de la couche de déchets non saturés et des taux de recharge du bassin de déchets.

À partir de l'évaluation de la banque de données, on peut conclure, que, dans une masse de déchets, de grandes variations des taux d'oxydation de sulfure et des taux de précipitation de fer existent, qui sont déterminées par des facteurs physiques, se produisant vraisemblablement pendant la déposition des déchets.

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1.0 INTRODUCTION

1.1 Background

Acid mine drainage from pyritic wastes associated with mining is an environmental and economic problem for which acceptable solutions have to be found. A biotechnological approach to waste water treatment is taken in Ecological Engineering and Biological Polishing, an ecological technology for the close out of acid generating wastes. Ecological Engineering technology is implemented by promoting natural water cleansing processes though engineering the waste site in such a way, that the proliferation of specific aquatic plants, microbial alkalinity generating and sulphate reducing ecosystems work together with the geochemical processes. The latter processes are those which result in the contaminant release to the surface water. Their dynamics in the acid generating wastes determines the dimensions of the Ecological Engineered system required.

The South Bay tailings site is located on the east shore of Confederation Lake, approximately 65 km northeast of the Town of Ear falls, Ontario (Figure 1A). The site contains tailings from a zinc/copper concentrator which was operated by BP-Selco from 1971 to 1981.

By 1985, oxidation of sulfide minerals in the tailings was producing acidic seepage with elevated iron and zinc contents, which affected water quality in Boomerang Lake. In the fall of 1986, close-out studies were undertaken for BP-Selco (now BP Mining) by Boojum Research Limited of Toronto. The aim of the studies was to design a close-out scenario that would minimize or eliminate the release of heavy metals from the site to surface waters in the area.

As part of those studies a number of piezometers was installed in and around the tailings basin and the mine site during October 1986. Since that time a large set of data on water levels, subsurface temperatures, and composition of subsurface water in and below the tailings has been accumulated. The evaluation of the available data presented in this report was undertaken to attempt determination of (1) the rate of acid generation and release from the tailings area, and (2) the rate of loss of iron and other metals from solution by precipitation within the tailings.

1.2 Data Sources

Information made available for the South Bay Tailings Site study covered by this report included the following:

1. Maps of local topography, dated May 1971 and February 1987; the 1987 map is based on October 1986 photography.
2. Analyses of tailings.
3. Driller's logs and installation data for 58 of the 70 piezometers and standpipes in the area.
4. Water-level measurements taken in the piezometers and standpipes, at irregular intervals in the periods 15 October 1986 to 23 August 1988, and 22 July to 15 October 1989.
5. Bottom-temperature measurements in 62 of the piezometers, taken on 1 April and 18 July 1987.
6. Temperature measurements from a 2.44 m long cable with 11 thermistors, installed in tailings, taken at irregular intervals in the periods 31 October 1986 to 16 June 1988, and 10 June to 15 October 1989.
7. Daily measurements of precipitation and air temperature for Ear Falls (Ontario), the closest weather station, 65 km southwest of the study site, for the period 1 September 1986 to 31 October 1989, as well as monthly precipitation totals for 1971-1989 and climate normals for 1951-1980.
8. ICP elemental analyses of a total of 175 water samples collected from piezometers on the site on several occasions between early-November 1986 and mid-October 1989.

The present study was concentrated on the tailings basin, which includes 26 of the piezometers in the area (Figure 1B). The piezometer sites that contain two piezometers each are marked in Figure 1B with the number and letter indicating the shallowest of the two piezometers.

2.0 RESULTS AND DISCUSSIONS

2.1 Tailings

The total quantity of tailings in the South Bay tailings basin is estimated by BP-Selco at between 735,000 and 785,000 short tons, covering an area of about 200,000 m^2. For the purpose of this report it is assumed that 760,000 short tons of tailings were placed in the basin. The tailings were reported to consist of approximately 41.1% pyrite, 4.1% pyrrhotite, 0.63% sphalerite, and 0.14% chalcopyrite, with the remainder consisting of silicates and about 1.0% calcite or lime. Chemical analyses and particle-size analyses of 7 samples of tailings collected by Boojum Research Limited are listed for comparison in Appendix A.

Based on excavating holes in the vegetation or fill covered tailings an average thickness of inert fill of 30 to 50 cm was determined. However, in searching the records, it appeared that BP-

Selco had contracted and aver fill cover to be spread over the tailings of only 15 cm.

Calcium in the form of lime or limestone has been added to the tailings at various times. Lime was added during ore processing, at a rate of 2.8 lbs per short ton of ore, for a total of about 965,000 kg of $Ca(OH)_2$. Every year from 1971 to 1981 about 30 short tons of lime were dumped into Decant Pond, for a total of about 270,000 kg. After the shutdown of operations, about 45,000 kg of agricultural limestone was spread on test plots on the tailings.

The areal distribution and total quantity of tailings were approximated on the basis of the 1971 and 1987 contour maps of the site. As contour intervals were 5 feet on the 1971 map, and 1 or 2 feet on the 1987 map, approximate 1 foot contours were interpolated for the tailings area on the 1971 map. Elevations in feet, taken from both maps on a 100 ft (30 m) grid were contoured by computer to produce Figures 2A and 2B. The elevation difference in metres between 1987 and 1971, for each of the grid points in the tailings area, reduced by 40 cm to account for the presence of the fill cover, was used to calculate tailings thickness for one set of calculations. A second set of calculations was carried out assuming a cover thickness of 15 cm fill.

The resulting tailings thicknesses (40 cm fill) were contoured to produce the tailings isopach map, Figure 3A. The accuracy of the tailings isopachs is probably no better than q 0.3 m vertical and 30 m horizontal.

The total quantity of tailings was calculated by multiplying the average tailings thickness for each grid block with the grid-block area, and summing the results for the whole basin.

2.2 Borehole Logs and Piezometer Data

2.2.1 Borehole Logs

The original driller's logs for the holes drilled in the tailings area in 1986 make no mention of "fill". Information based on excavating holes in the tailings surface indicated that fill thickness was about 30 to 50 cm was spread over the tailings. However BP-Selco had contracted for an average fill thickness of about 15 cm. The available driller's logs, with allowance for an average of 40 cm fill, indicate tailings thicknesses ranging from 1.28 to 4.78 m (Appendix B-1 and Figure 3B). The driller's logs adjusted for the 15 cm fill results in tailings thicknesses ranging from 1.53 to 5.03 m (Appendix K-1).

No logs are available for the 8 piezometers installed in the tailings area in 1985 (H1 to H8 in Figure 1B), prior to the onset of the study.

2.2.2 Piezometer Data

Location coordinates and installation data for the piezometers in the tailings basin are given in Appendix B-2, which also lists the material in which the piezometers are screened. Piezometer locations are shown in Figure 1B. Hydraulic conductivities of the materials surrounding the piezometer screens were determined from recovery tests after bailing, performed shortly after completion of the piezometers in the fall of 1986.

A reported requirement for the 1986 drilling program was to install several pairs of piezometers in the tailings basin, with one piezometer screen of each pair in tailings, and the other in unconsolidated sediments below the tailings. This requirement was satisfied only at site 7. At site 27, both piezometer screens are situated in tailings; at sites 5 and 24, both screens are located in sediments below the tailings.

2.3 Water Levels

2.3.1 Water-Level Measurements

During the study period from 15 October 1986 to 15 October 1989, water levels in piezometers in the South Bay area have been measured at intervals ranging from less than a week to as much as 11 months. Intervals became excessive after 17 January 1988 (25 April, 16 June, 23 August; restarted on 22 July 1989). In several instances the available data showed single-point "spikes" (positive or negative), where the water level rose (or fell) by approximately 1 m, followed by a return to the original level by the time of the next measurement. A number of these spikes turned out to represent transcription or measurement errors; where possible, these errors in the record were corrected during the current evaluation.

Water-level data for the 26 piezometers in the tailings basin (11 in tailings, and 15 in unconsolidated sediments below the tailings) have been extracted from the data base, and processed to calculate water-level elevations and depths of water below ground in the tailings basin (Appendix C). The variations in water-level elevation for individual piezometers are shown in Figures 4A to 4E. Minimum water-level elevations occur in late winter, maximum water-level elevations by the end of the snowmelt period in spring.

Secondary water-level highs are related to periods of high rainfall, but correlation between the water levels and rainfall data for Ear Falls (Figure 5A) are at best sketchy.

It can be presumed that the water-level rise during the snowmelt period depends on the amount of winter snowfall, particularly the amount of snow left on the ground at the start of the snowmelt, and on the porosity of the ground. As a result of the gaps in the water-level records, approximate late-winter lows and early-spring highs in the water levels are known only for 1987.

Figure 5B shows the separation of monthly precipitation at Ear Falls into rain and snow. Data on the depth of snow cover on the tailings basin in early 1987 are listed in Appendix E; the distribution of snow depths on 15 March 1987 is shown in Figure 5C. A further 14 cm of snow and 8.2 mm of rain fell on 25 and 26 March. Daily-mean air temperatures were above 0°C from 16 to 24 March and from 4 April onwards (cf. Figure 10A for Ear Falls).

The relationship between snow depth on 15 March and the rise in water levels between 15 March and 15 April is illustrated by Figure 5D. Assuming water equivalents of 20% and 10% for the snow cover and the freshly fallen snow, respectively, and infiltration of essentially all meltwater and rain, one finds that the observed

rise in water level reflects apparent porosities ranging from 6.5 to 33%, with an average of 16%. As the observed rise in water-level was counteracted by the occurrence of downward movement of the groundwater, actual porosities are undoubtedly higher.

Figures 4A to 4E indicate small variations in the magnitude of hydraulic gradients between piezometer locations, but no reversals in gradient directions. Water levels drop below the bottom of at least 3 of the piezometers (H1, H2 and H3) in the tailings during late winter.

2.3.2 Unsaturated Tailings Thickness

Oxidation of sulfide minerals in tailings presumably requires the availability of both oxygen (air) and water. As the concentration and rate of diffusion of oxygen are considerably lower in water than in air, it can be assumed that most of the sulfide oxidation (and acid generation) is concentrated in the unsaturated portion of the tailings. Therefore the maximum and minimum unsaturated thickness of tailings have been calculated for each piezometer location.

Figures 6A and 6B show the distribution of the maximum and minimum depth-of-water-below-ground values, listed in Appendix D. These

values and the tailings thicknesses from the borehole logs (Appendix B-1) have been used to determine the distribution of minimum and maximum thickness of unsaturated tailings. The results are listed in Appendix D, and illustrated in Figures 7A and 7B.

Due to the seasonal variations in water levels, the thickness of unsaturated tailings varied, with maximum values ranging from 0.67 to 3.53 m, and minimum values ranging from 0 to 2.68 m, for individual piezometer locations. The significance of a fill cover thickness in relation to the unsaturated tailings mass can be seen from the second set of maximum values which range from 0.92 to 3.78 m and minium values ranging from 0 to 2.93 m when fill cover is assumed to be 15 cm. The data are presented in Appendix L-1.

2.4 Subsurface Temperatures

Bottom temperatures have been measured twice in most of the piezometers in the tailings basin, on 1 April and 18 July 1987, using an electronic thermometer. The results (Appendix E) are probably accurate to within 0.5°C. They are shown in a temperature vs. depth plot in Figure 8A. Maximum temperatures decreased, and minimum temperatures increased, with increasing depth. The maximum and minimum measured temperatures were 17.0 and 2.8°C, respectively. No "hot spots" were apparent. A temperature

difference vs. depth plot is shown in Figure 8B; it shows that the temperature difference, ranging from 2.9 to 14.2°C, decreased with increasing depth, as expected.

Periodic temperature measurements, on a 2.44 m long cable with 11 thermistors installed in tailings between piezometer sites 4 and 5 (see Figure 1B), were taken at irregular intervals in the periods 31 October 1986 to 16 June 1988, and 10 June to 15 October 1989 (Appendix F). The data, probably also accurate to within 0.5°C, are illustrated by temperature vs. time plots in Figures 9A and 9B; note that the curve for the thermistor at 0.91 m depth is included in both plots.

The measurement frequency has been too low to enable any detailed correlation of the measured subsurface temperatures with the fluctuations in daily-mean air temperatures shown in Figure 10A (temperature normals for Ear Falls for the period 1951-1980 are listed in Appendix G, and shown in Figure 10B for comparison).

The available data show that temperatures fell below 0zC only in the upper 30 cm (Figure 11A), which reportedly consist of inert fill cover. The tailings thus appear not to have been affected by freezing. This suggests that the bacterial oxidation of sulfide

minerals in the tailings, although depressed by low winter temperatures, would not be subjected to temperatures below 0°C.

Freezing-point depression in water in the tailings basin, ranging from -0.05 to -1.52°C (see T-freezing in Appendix I), would tend to delay freezing of saturated tailings somewhat. Near the thermistor site, the depth-to-water curves for piezometers 4, 5A and 5B indicate that saturated conditions probably occurred only around the lowest two thermistors, well below the depth of frost penetration (Figure 11B).

2.5 Water Chemistry

2.5.1 Chemical Analyses

Chemical (ICP) analyses of 59 samples, collected from the 26 piezometers in the tailings basin at several times between October 1986 and October 1989, have been extracted from the data base (Appendix H). The analyses did not include determinations of chloride or nitrate/nitrite. Acidity values were given for about half the samples, but alkalinity values were not given, although pH values range up to 7.1. Water temperatures measured at the time of sampling were available for less than half the samples; field pH values for all the samples; field conductivity values for about

half the samples, and lab conductivity values for most of the remaining samples.

As both pH and conductivity measurements, as well as filtering and acidification of the samples, were commonly carried out in the field laboratory within 24 h after collection of the samples, it is likely that both the field measurements and the analytical results contain various amounts of "noise" introduced by early changes in the samples (particularly precipitation of iron-hydroxide). The pH data, moreover, may well reflect the varying degrees to which the pH electrodes were affected by repeated measurements in highly acidic waters with high heavy-metal contents.

It was discovered that erroneous [Fe] values were given by Assayers Ontario in at least 12 of the samples collected in July 1987 ([Fe] all equal to 289 or 290 mg/L) and at least 24 of the samples collected in April 1988 ([Fe] all equal to 311 mg/L). The April 1988 samples have been re-analyzed for Fe concentrations in November 1989; the results, incorporated in Appendix H, likely have produced some additional noise into the data set. The July 1987 samples could not be re-analyzed because they were no longer available; the original analyses, with [Fe] marked by stars in Appendix H, have been used only in some geochemical evaluation.

For the following discussions it is assumed that the sulfur concentration [S] represents dissolved sulfate. Disregarding the extreme values for the April 1988 sample from piezometer H8, sulfur (sulfate) concentrations range from 12.0 to 6735 (36.0 to 20,180) $mg.L^{-1}$; iron concentrations from 0.36 to 9938 $mg.L^{-1}$; and zinc concentrations from 0.33 to 1123 $mg.L^{-1}$.

As pyrite and or pyrrhotite can be assumed to be the main sources of sulphate and iron in the porewater of the tailings on could expect to find a correlation between these two elements. However the large concentration ranges found between [S] or [Fe] and maximum or minimum unsaturated or saturated thickness of the tailings does not suggest an obvious correlation.

2.5.2 Geochemical Calculations

For the purpose of the geochemical calculations, $millimole.L^{-1}$ values have been calculated from the $mg.L^{-1}$ values in Appendix H.

Concentrations of major elemental components were converted to milliequivalents per litre, for the calculation of apparent ion-balance error = (cations - anions)/(cations + anions) x 100. The resulting values ranged from -91.6 to +68.1 % (Appendix I); the

large apparent balance errors undoubtedly reflect the absence of values for alkalinity and chloride, and uncertainties in Fe values.

Approximate values for freezing-point depression, referred to earlier, were calculated as $kT_f = M * K_f$, where M is the sum of concentrations of the various elements in the sample, and K_f the molal freezing-point depression for water. The resulting values range from -0.05 to -1.52°C (Appendix I).

Logarithmic values were calculated for [S], [Fe], [Ca], and [Zn], to make it easier to compare changes in the concentrations of these elements with time, for individual piezometers. The results are shown in Figure 12A for piezometers screened in tailings, and in Figure 12B for piezometers screened below the tailings.

For the less concentrated samples, [Ca] and [Zn] appear to increase together with [S] and [Fe], respectively. In more concentrated samples, [Ca] reaches a maximum value well below [S], while [Fe] approaches [S], as lower pH values keep more Fe in solution.

To explore the relationships between some of the elements further, the available analyses have been sorted into two sequences of decreasing log[Fe], separately for the samples from tailings and for the samples from below tailings. Figure 13A shows line plots

of log[S], log[Fe], log[Na], log[Ca], and log[Zn] for the samples from tailings; Figure 13B shows the same for samples from below tailings.

Both plots show log[Fe] exceeding log[S] only at the high end (where pH is low), falling faster than log[S] towards lower concentrations (where higher pH values tend to encourage precipitation of $Fe(OH)_3$). Log[Zn], more than a full log unit below log[Fe] at the high end, is approached by log[Fe] at the low end, suggesting that Zn does not co-precipitate proportionally with Fe. Log[Ca] equals or exceeds Log[S] at the low end (indicating Ca dissolution keeps pace with acid production), but for increasing log[S] values above 1.2 the log[Ca] values slowly decrease, likely reflecting progressive precipitation of gypsum ($CaSO_4.2H_2O$) when sulfate concentration increases.

For the samples from tailings, log[Na] values are above 0 and exceed log[Fe] values for [Fe] lower than 1.0 millimole.L^{-1}, but they decrease to values below zero for higher [Fe], suggesting that precipitation of natro-jarosite may occur here.

Fe/SO_4 ratios were calculated to assist in the determination of apparent Fe and S loss. Two sets of calculation results are shown in Appendix I, for pyrrhotite and pyrite as the possible sources

of the S and Fe. The results suggest that (a) pyrrhotite rather than pyrite may be the prime source of the dissolved iron and sulfate in at least a few of the samples; (b) in some cases part of the initial Fe content is subsequently precipitated in the tailings pile (and possibly in the underlying sediments), probably mostly in the form of iron-hydroxide; and (c) some of the initial sulfate may also be lost from solution, probably by precipitation of gypsum. These points are illustrated by the plot of [Fe] vs. [S] in Figure 13C. The chemical analyses further suggest that other elements such as Zn are precipitated with Fe.

2.5.3 Sulfide-Oxidation and Iron-Precipitation Rates

Using the available chemical analyses, the thickness of unsaturated tailings, and the estimated amount of annual recharge at the site, apparent rates of **sulfide-oxidation** and **iron-precipitation** have been calculated (Appendix J for unsaturated tailings thickness with 40 cm fill cover assumed and Appendix M for unsaturated tailings thickness with 15 cm fill cover assumed.

The apparent sulfide-oxidation rates for 40 cm fill range from 0.0001 to 0.0135 $mol.kg^{-1}.yr^{-1}$ (overall average 0.0057 $mol.kg^{-1}.yr^{-1}$) and for 15 cm fill a range of 0.0001 to 0.0117 $mol.kg^{-1}.yr^{-1}$ (overall average 0.0031 $mol.kg^{-1}.yr^{-1}$). Because of temperature

effects, rates would be higher than this during hot summers, and lower in winter. Calculated apparent iron-precipitation rates for the 40 cm fill range from 0.00001 to 0.00155 $mol.kg^{-1}.yr^{-1}$ (overall average 0.000386 $mol.kg^{-1}.yr^{-1}$) which are reduced to 0.000009 to 0.00092 $mol.kg^{-1}.yr^{-1}$ (overall average 0.00024 $mol.kg^{-1}.yr^{-1}$) with a 15 cm fill cover. Iron precipitation would likely be enhanced by increased infiltration of rain and snowmelt with a higher pH.

Results of calculations of the degree of saturation of the samples with respect to gypsum are listed in Appendix I, and illustrated by Figure 14A. The values range from -3.27 to +0.47. The negative values correspond to low sulfate concentrations; saturation appears to occur at sulfate concentrations of about 12 $millimoles.L^{-1}$. At least 33 of the analyses gave positive values, indicating that many of the samples were saturated with respect to gypsum. It is therefore likely that most of the samples with higher sulfate concentrations in and below the tailings have experienced not only loss of Fe by precipitation, but also loss of some SO_4^{2-} by precipitation of gypsum. Gypsum precipitation will likely be enhanced during dry summers, and reduced (possibly leading to some re-dissolution) during wet summers. Minor amounts of sulfate may be converted to H_2S by bacterial action.

The relationship between [Na] and [S] in the samples, illustrated by Figure 14B, shows an increase in [Na] with increasing [S] below about 10 millimole.L^{-1}, followed by a levelling off, and a gradual decrease for [S] above about 75 millimole.L^{-1}. This suggests that Na and S contribute to precipitation of Fe in the form of natro-jarosite.

The available data do not allow estimates of the amount of Fe precipitated in the form of jarosite, or of the amount of S precipitated in the form of gypsum. Tailings samples have so far not been analyzed to determine what precipitate minerals are present.

3.0 CONCLUSIONS

Due to the seasonal variations in water levels, the thickness of unsaturated tailings varied, with maximum values ranging from 0.67 to 3.53 m, and minimum values ranging from 0 to 2.68 m, for individual piezometer locations for 0.40 m fill thickness. The differences for the unsaturated tailings thickness due to the placement of either a thinner or thicker inert cover have been demonstrated by comparison of these values with a fill thickness of 15 cm.

Available data on subsurface temperatures show that temperatures fell below 0°C only in the upper 30 cm in the tailings basin, which is in the depth ranges which consist of "inert" fill cover. The tailings thus appear not to have been affected by freezing. Moreover, freezing points calculated for water samples from the tailings basin range from -0.05 to -1.52°C.

Water samples for chemical analysis have been collected from most of the piezometers several times during the study period. Although values of [Fe] for a number of samples taken in July 1987 and April 1988 were found to be erroneous, the remaining data clearly reflect the occurrence of oxidation of sulfide minerals in the tailings basin. Sulfate concentrations range from 36.0 to 20,180 $mg.L^{-1}$; iron concentrations from 0.36 to 9938 $mg.L^{-1}$; and zinc concentrations from 0.33 to 1123 $mg.L^{-1}$.

The results of the chemical analyses suggest that some of the initial Fe content is subsequently precipitated in the tailings pile (and possibly in the underlying sediments), probably in the form of iron-hydroxide and some Na-jarosite, and that some of the initial sulfate is lost from solution by precipitation of gypsum (approximate saturation degrees for gypsum range from -3.27 to +0.47). Minor amounts of sulfate may be converted to H_2S by

bacterial action. The chemical analyses further suggest that other elements such as Zn are co-precipitated with Fe.

Using the available chemical analyses and the estimated amount of annual recharge at the site, apparent **sulfide-oxidation rates** have been calculated for assumed cover thicknesses of 40 cm and 15 cm; they range from 0.0001 to 0.0135 $mol.kg^{-1}.yr^{-1}$ (overall average 0.0057 $mol.kg^{-1}.yr^{-1}$) for a cover of 40 cm and are slightly lower for a thinner cover. Calculated apparent **iron-precipitation rates** range from 0.00001 to 0.00155 $mol.kg^{-1}.yr^{-1}$ (overall average 0.000386 $mol.kg^{-1}.yr^{-1}$) for an assumed cover with 40 cm fill, and they are also lower when the assumed fill thickness is reduced to 15 cm. The available data do not allow estimates of the amount of Fe precipitated in the form of jarosite, or of the amount of S precipitated in the form of gypsum.

It should be kept in mind that the rates calculated for this report are <u>apparent</u> only. They are based on available water analyses and <u>assumed</u> cover thicknesses (which, together with water-level data, determine (partly assumed) unsaturated thicknesses of tailings). When thinner cover is assumed, a <u>larger thickness</u> of unsaturated tailings would have produced the <u>same quantities of oxidation products</u> (indicated by the water chemistry) through slightly <u>lower APPARENT oxidation rates</u>.

However, in actual fact a thinner cover would give larger unsaturated tailings thickness which, for a given oxidation rate, would produce more dissolved contaminants, leading to higher concentrations in the tailings water.

4.0 RECOMMENDATIONS

Samples for mineral analysis should be collected from tailings in and below the zone of water-level fluctuation, and such samples should be analyzed for the presence of iron-hydroxide, jarosite and gypsum to confirm the proposed precipitation of these minerals which appears to occur in the tailings.

Accumulated precipitate in the groundwater interceptor ditch and retention pond should be sampled for mineral analysis, even though it is likely mixed with a significant amount of sediment eroded from the side slopes of the ditch and pond. This would provide information on the form in which the contaminants leave the tailings and enter the Biological Polishing system.

Samples for chemical analysis should be collected from:

(a) discharge entering the groundwater interceptor ditch on the south side of the tailings basin;

(b) water in the retention pond downstream of the ditch.

The apparent rates of production of contaminants within the tailings pile are, as demonstrated, quite sensitive to variations in water level (reflecting variations in recharge rates) and to assumed thickness of inert fill, as those affect the calculated unsaturated mass of the tailings undergoing oxidation. To document the relationship between precipitation and water levels in the tailings in the study area, it will be necessary to verify the degree of validity of weather data from the Ear Falls weather station for the South Bay tailings site. Reportedly, a 14-year precipitation and temperature records exist for a weather station operated at the former South Bay Mine; those records should be compared to the data for the same period from the Ear Falls station.

Measurement of water levels at regular intervals should be continued, to enable more adequate correlation with snowmelt and rainfall events, and determination of actual recharge rates.

ANALYSES OF TAILINGS SAMPLES (% DRY WEIGHT)

PIEZOMETER #	H2/1	H2/2	M46/1	M46/2	M43	M40	M26
INTERVAL	16"-18"	6'-8'	18"-20"	20"-24"	4'-8'	5'-7'	5'-7'
Al2O3	6.89	4.3	3.9	4.4	4.8	5.9	7.3
Fe	10.21	25.18	27.98	24.48	23.08	19.58	17.49
CaO	1.4	0.8	0.9	1	1.3	0.7	1.3
MgO	0.3	0.7	0.4	0.4	0.8	0.6	0.9
Na2O	2	1	2.2	2	2.1	1.3	2.1
K2O	1.5	0.7	0.9	0.9	0.8	1.1	1.5
TiO2	0.1	0.06	0.06	0.06	0.1	0.05	0.07
MnO	0.02	0.3	0.04	0.05	0.2	0.1	0.09
P2O5	0.1	0.2	0.2	0.2	0.2	0.1	0.2
As	0.1	0.3	0.3	0.4	0.3	0.1	0.1
B	0.1	0.05	0.2	0.2	0.1	0.1	0.2
Ba	0.01	0.008	0.01	0.01	0.009	0.01	0.01
Bi	0.03	0.03	0.04	0.03	0.04	0.03	0.03
Cd	0.001	0.01	0.01	0.03	0.01	0.01	0.005
Ce	0.006	0.009	0.004	0.004	0.004	0.007	0.008
Co	0.01	0.03	0.03	0.02	0.03	0.01	0.01
Cr	0.001	0.004	0.003	0.002	0.01	0.007	0.004
Cu	0.03	0.54	0.57	0.87	1.1	0.14	0.14
La	0.02	0.003	0.001	0.001	0.001	0.003	0.003
Mo	0.01	0.01	0.01	0.01	0.009	0.009	0.008
Nb	0.002	0.005	0.004	0.004	0.005	0.003	0.003
Ni	0.002	0.007	0.007	0.006	0.006	0.006	0.006
Pb	0.17	0.24	0.004	0.34	0.2	0.17	0.16
S	8.93	23.8	28.2	22.1	21.2	17.1	14.6
Sb	0.03	0.05	0.05	0.05	0.05	0.03	0.03
Se	0.03	0.07	0.08	0.07	0.06	0.06	0.06
Sn	0.02	0.02	0.03	0.02	0.02	0.02	0.02
Sr	0.007	0.004	0.004	0.003	0.006	0.006	0.009
Te	0.01	0.04	0.04	0.06	0.04	0.04	0.02
Th	0.009	0.02	0.02	0.01	0.01	0.01	0.01
U	0.05	0.1	0.1	0.1	0.1	0.08	0.08
V	0.002	0.001	0.001	0.001	0.002	0.002	0.003
W	0.01	0.05	0.04	0.09	0.05	0.05	0.03
Y	0.002	0.002	0.001	0.001	0.002	0.001	0.002
Zn	0.04	2.1	1.5	4.1	1.8	2	0.89
Zr	0.04	0.02	0.02	0.02	0.02	0.02	0.03
L.O.I.	11.15	18.22	21.4	20.11	16.87	14	12.51
Sum	43.3	79.0	89.3	82.2	75.4	63.5	59.9
Missing	56.7	21.0	10.7	17.8	24.6	36.5	40.1
Sum Al, Ca, Na, K, Mg oxides:	12.1	7.5	8.3	8.7	9.8	9.6	13.1
Sum Fe, Cu, Pb, Zn ("Fe+"):	10.5	28.1	30.1	29.8	26.2	21.9	18.7
Sum "Fe" + S: (*)	19.4	51.9	58.3	51.9	47.4	39.0	33.3
Sum Minor Elements:	0.7	1.4	1.3	1.5	1.4	0.9	1.0
S, mole/100 g	0.28	0.74	0.88	0.69	0.66	0.53	0.46
"Fe+",mole/100 g	0.18	0.49	0.53	0.52	0.46	0.38	0.33
"Fe+"/S	0.66	0.66	0.61	0.75	0.69	0.72	0.72

(*) - Average 43.0 percent

PARTICLE-SIZE ANALYSES OF TAILINGS (*)

PIEZOMETER SITE	INTERVAL	SILT %	FINE SAND %	MEDIUM SAND %
H 2	16"-18"	25	70	5
H 2	6'-8'	20	55	25
M 46	18"-20"	20	65	15
M 46	20"-24"	40	60	0
M 43	4'-8'	30	48	22
M 40	5'-7'	20	60	20
M 27	5'-7'	20	68	12
RANGES, %		20 - 40	48 - 70	0 - 25
AVERAGES, %		25.0	60.9	14.1

(*) - On the basis of these results, average porosity for the tailings has been assumed to be about 30 percent.

SOUTH BAY - BOREHOLE LOGS (in metres)

Piezom. No.		Fill	Tailings	Peat	Sand	Gravel	Bedrock	T.D.
4	B	0.40	2.80	0.03	4.39	0.00	2.13	9.75
5A	B	0.40	1.28	0.03	12.62	0.00	0.00	14.33
5B	B	0.40	1.28	0.03	3.63	0.00	0.00	5.34
7A	T	0.40	4.78	0.00	0.00	0.00	0.00	5.18
7B	B	0.40	4.78	0.00	5.00	0.00	1.52	11.70
9	B	0.40	4.17	0.00	0.00	1.22	1.83	7.62
24A	B	0.40	1.73	0.06	6.10	0.00	0.00	8.29
24B	B	0.40	1.73	0.06	3.91	0.00	0.00	6.10
25	B	0.40	1.73	0.03	3.02	0.00	0.00	5.18
26	B	0.40	2.65	0.03	2.56	0.00	0.00	5.64
27A	T	0.40	4.78	0.92	0.00	0.00	0.00	6.10
27B	T	0.40	4.17	0.00	0.00	0.00	0.00	4.57
30	B	0.40	2.04	0.03	1.95	0.00	0.00	4.42
32	B	0.40	2.34	0.00	6.10	1.83	0.00	10.67
40	B	0.40	3.87	0.00	1.52	0.00	2.13	7.92
41	B	0.40	3.26	0.30	1.22	0.00	0.00	5.18
43	B	0.40	4.17	0.00	4.88	0.00	1.52	10.97
46	B	0.40	4.17	0.00	5.18	0.00	1.52	11.28
H1	T	0.40	1.70	0.00	0.00	0.00	0.00	2.10
H2	T	0.40	2.45	0.00	0.00	0.00	0.00	2.85
H3	T	0.40	2.49	0.00	0.00	0.00	0.00	2.89
H4	T	0.40	1.83	0.00	0.00	0.00	0.00	2.23
H5	T	0.40	2.01	0.00	0.00	0.00	0.00	2.41
H6	T	0.40	2.11	0.00	0.00	0.00	0.00	2.51
H7	T	0.40	2.49	0.00	0.00	0.00	0.00	2.89
H8	T	0.40	1.86	0.00	0.00	0.00	0.00	2.26

SOUTH BAY PIEZOMETER DATA

Piezom. No.	Coordinates(ft) Northing	Coordinates(ft) Easting	Stick-up m	Elevations, m AMSL: Ground	Collar	Screen Top	Screen Bottom	Screen Tip	Depth Drilled m	Depth Tip m	Hydraul. Cond. cm/sec	"Aquifer" Material
4	11130	16380	0.50	417.52	418.01	413.16	412.39	412.33	9.75	5.18	2.2E-03	Sand
5A	11020	16020	0.46	417.70	418.16	407.24	406.94	406.88	14.33	10.82	4.3E-03	C.Sand
5B	11020	16020	0.47	417.70	418.17	412.73	412.42	412.36	5.33	5.33	5.2E-05	C.Sand
7A	12505	15810	0.45	417.73	418.18	413.71	412.94	412.88	5.18	4.85	3.8E-06	TAILINGS
7B	12505	15810	0.21	417.73	417.94	407.55	407.24	407.18	11.77	10.55	7.7E-04	Sand
9	11885	15250	0.52	417.97	418.49	411.91	411.60	411.54	7.62	6.43	1.7E-04	Sand/Gr.
24A	11080	15300	0.35	417.79	418.14	410.35	409.59	409.53	8.29	8.26	7.1E-05	Sand
24B	11080	15300	0.39	417.79	418.18	413.25	412.49	412.42	6.10	5.36	7.7E-05	Sand
25	12485	16000	0.54	415.69	416.23	411.82	411.05	410.99	5.18	4.69	5.8E-05	Sand
26	12120	15940	0.45	416.48	416.93	411.82	411.05	410.99	5.64	5.49	3.8E-05	Sand
27A	11085	15750	0.65	417.39	418.04	413.22	412.46	412.39	6.10	5.00	2.1E-05	TAILINGS
27B	11085	15750	0.49	417.39	417.88	413.77	413.00	412.94	4.57	4.45	8.0E-06	TAILINGS
30	11700	16435	0.49	416.23	416.73	411.63	412.30	412.24	4.42	3.99	3.7E-04	Sand
32	12150	15500	0.31	417.94	418.25	415.26	407.58	407.55	10.67	10.39	2.1E-04	BR
40	11730	15890	0.65	417.67	418.32	412.15	411.39	411.33	7.92	6.34	1.1E-03	Sand/BR
41	11410	16075	0.78	417.45	418.23	413.37	412.61	412.55	5.18	4.91	1.2E-06	Sand
43	12360	15690	0.23	417.45	417.68	408.46	408.16	408.10	10.97	9.36	6.0E-04	Fine Sand
46	12020	15370	0.52	418.09	418.62	407.52	406.91	406.85	11.28	11.25	1.3E-02	Bedrock
H1	11705	15300	0.39	417.79	418.18	416.66	415.75	415.69	2.10	2.10	8.9E-05	TAILINGS
H2	11360	15220	0.53	417.88	418.41	415.99	415.08	415.02	2.85	2.87	3.6E-04	TAILINGS
H3	11225	15310	0.29	418.03	418.32	416.11	415.20	415.14	2.89	2.90	6.8E-06	TAILINGS
H4	11485	15400	0.60	417.58	418.18	416.33	415.41	415.35	2.23	2.23	4.8E-04	TAILINGS
H5	11730	15445	0.63	417.39	418.02	415.96	415.05	414.99	2.41	2.41	1.3E-04	TAILINGS
H6	11955	15505	0.29	417.70	417.99	416.17	415.26	415.20	2.51	2.50	3.1E-04	TAILINGS
H7	12020	15645	0.43	417.67	418.10	415.75	414.83	414.77	2.89	2.90	5.4E-03	TAILINGS
H8	11580	15490	0.48	418.06	418.54	416.78	415.87	415.81	2.26	2.26	1.5E-04	TAILINGS

DEPTH of WATER below GROUND, m

Piezom. No.	15-Oct-86 31700 XXXXX	05-Nov-86 31721 XXXXX	22-Nov-86 31738	30-Nov-86 31746	07-Dec-86 31753	14-Dec-86 31760	21-Dec-86 31767	28-Dec-86 31774	04-Jan-87 31781	11-Jan-87 31788	25-Jan-87 31802	08-Feb-87 31816
4	3.20	3.23	3.26	3.29	3.31	3.33	3.37	3.35	3.37	3.38	3.40	3.43
5A	3.29	3.38	3.44	3.47	3.49	3.52	3.52	3.54	3.56	3.57	3.59	3.63
5B	2.01	2.74							2.85	2.85	2.88	2.88
7A	2.44	2.53							2.87	2.84	2.93	2.98
7B	2.80	2.83							3.09	3.08	3.14	3.19
9	3.38	3.32	3.42	3.45	3.47	3.50	3.50	3.53	3.54	3.54	3.58	3.63
24A	3.26	3.38	3.52	3.53	3.56	3.59	3.61	3.63	3.65	3.65	3.69	3.71
24B	3.20	3.26	3.42	3.45	3.48	3.51	3.52	3.55	3.56	3.58	3.61	3.64
25	0.58	0.58							0.83	0.82	0.90	0.94
26	0.64	0.70							0.79	0.74	0.85	0.89
27A	1.16	1.58							2.15	2.32	2.29	2.41
27B	0.49	1.25							1.87	1.86	2.03	2.17
30	0.37	0.61							0.79	0.79	0.91	0.94
32	3.20	3.20							3.41	2.99	3.46	3.51
40	1.74	2.13							2.35	2.35	2.53	2.59
41	0.31	0.40							0.71	0.70	0.95	1.11
43	2.07	2.44							2.79	2.77	2.96	2.92
46	3.69	3.41	3.53	3.58	3.59	3.60	3.63	3.65	3.66	3.66	3.72	3.76
H1	1.19	1.37	1.68	1.71	1.74	1.78	1.78	1.81	1.81	1.87	1.95	1.96
H2	1.62	1.77	2.03	2.07	2.10	2.13	2.15	2.17	2.20	2.22	2.30	2.37
H3	1.61	1.86	2.21	2.24	2.26	2.30	2.33	2.36	2.40	2.41	2.55	2.68
H4	0.31	0.40	0.72	0.74	0.79	0.84	0.83	0.86	0.88	0.86	1.14	1.25
H5	0.37	0.49	0.67	0.70	0.73	0.77	0.77	0.79	0.81	0.81	0.98	1.08
H6	1.37	1.49	1.68	1.74	1.75	1.79	1.78	1.81	1.81	1.82	1.91	1.99
H7	1.62	1.71	1.87	1.87	1.90	1.94	1.93	1.95	1.96	1.97	2.06	2.15
H8	0.61	0.73	1.00	1.00	1.06	1.09	1.07	1.09	1.11	1.10	1.35	1.50

DEPTH of WATER below GROUND, m

Piezom. No.	15-Feb-87 31823	21-Feb-87 31829	01-Mar-87 31837	15-Mar-87 31851	29-Mar-87 31865	15-Apr-87 31882	29-Apr-87 31896	06-May-87 31903	14-May-87 31911	23-May-87 31920	03-Jun-87 31931	11-Jun-87 31939
4	3.44	3.44	3.43	3.45	3.35	3.05	3.12	3.17	3.23	3.25	3.24	3.25
5A	3.64	3.66	3.64	3.64	3.56	3.19	3.27	3.32	3.38	3.41	3.40	3.42
5B	2.89	2.88	2.93	2.91	2.78	2.24	2.29	2.39	2.48	2.53	2.55	2.55
7A	2.99	3.02	3.01	3.02	2.81	2.31	2.37	2.41	2.55	2.61	2.63	2.48
7B	3.20	3.22	3.22	3.19	2.99	2.49	2.67	2.69	2.86	2.89	2.91	2.79
9	3.65	3.67	3.65	3.66	3.52	2.98	3.07	3.11	3.23	3.28	3.33	3.26
24A	3.72	3.71	3.74	3.75	3.65	3.25	3.32	3.37	3.43	3.45	3.49	3.51
24B	3.66	3.68	3.68	3.69	3.61	3.09	3.13	3.20	3.29	3.33	3.36	3.36
25	0.94	0.93	0.96	0.94	0.74	0.28	0.43	0.49	0.60	0.62	0.65	0.54
26	0.87	0.88	0.84	0.79	0.66	0.63	0.71	0.76	0.82	0.80	0.82	0.66
27A	2.43	2.43	2.44	2.34	1.89		1.34	1.37	1.79	1.77	1.77	1.75
27B	2.19	2.20	2.21	2.09	1.56		1.02	1.05	1.56	1.51	1.52	1.54
30	0.96	0.96	0.94	0.89	0.45	0.32	0.46	0.47	0.61	0.47	0.50	0.40
32	3.52	3.50	3.53	3.51	3.34	2.81	2.96	3.00	3.13	3.17	3.20	3.11
40	2.62	2.64	2.58	2.49	2.00	1.80	2.05	2.07	2.27	2.09	2.03	1.98
41	1.12	1.14	1.13	0.97	0.57	0.34	0.51	0.55	0.81	0.72	0.75	0.34
43	2.94	2.94	2.96	2.95	2.69	1.95	2.17	2.18	2.39	2.45	2.48	2.33
46	3.68	3.80	3.78	3.78	3.61	3.08	3.21	3.29	3.38	3.42	3.41	3.36
H1	1.96	1.96	1.96	1.95	1.21	0.56	1.16	1.40	1.61	1.48	1.22	1.34
H2	2.42	2.45	2.47	2.41	2.02	1.57	1.74	1.83	1.93	1.88	1.73	1.82
H3	2.71	2.73	2.75	2.61	2.05	1.08	1.62	1.82	2.01	1.96	1.71	1.84
H4	1.27	1.32	1.25	1.08	0.24	0.13	0.52	0.79	0.97	0.71	0.44	0.53
H5	1.11	1.13	1.12	0.98	0.33	0.19	0.46	0.63	0.75	0.59	0.46	0.48
H6	2.03	2.02	2.05	1.98	1.50	1.11	1.38	1.48	1.61	1.51	1.44	1.43
H7	2.17	2.16	2.20	2.09	1.65	1.46	1.63	1.71	1.81	1.70	1.66	1.62
H8	1.52	1.55	1.52	1.30	0.56	0.50	0.82	1.04	1.22	0.96	0.69	0.78

DEPTH of WATER below GROUND, m

Piezom. No.	20-Jun-87 31948	28-Jun-87 31956	05-Jul-87 31963	18-Jul-87 31976	15-Aug-87 32004	25-Sep-87 32045	06-Oct-87 32056	12-Nov-87 32093	14-Dec-87 32125	17-Jan-88 32159	08-Apr-88 32241	25-Apr-88 32258
4	3.28	3.32	3.34	3.35	3.40	3.43	3.44	3.43	3.44	3.49	3.39	3.19
5A	3.44	3.48	3.51	3.52	3.56	3.62	3.62	3.64	3.64	3.67	3.74	3.37
5B	2.55	2.60	2.65	2.66	2.67	2.68	2.71	2.72	2.74	2.80	2.88	2.56
7A	2.51	2.58	2.59	2.71	2.78	2.91	2.97	3.00	3.13	3.11	3.09	2.74
7B	2.83	2.91	2.94	2.98	3.07	3.18	3.23	3.25	3.34	3.42	3.40	2.89
9	3.31	3.36	3.40	3.45	3.52	3.61	3.66	3.68	3.74	3.80	3.78	3.39
24A	3.53	3.58	3.59	3.62	3.67	3.72	3.73	3.73	3.75	3.77	3.95	3.46
24B	3.40	3.44	3.47	3.51	3.59	3.65	3.68	3.67	3.70	3.75	3.71	3.39
25	0.59	0.66	0.71	0.73	0.80	0.93	0.98	0.97	1.05	1.12		0.64
26	0.73	0.80	0.81	0.83	0.83	0.95	0.99	0.86	1.04	1.07	0.89	0.74
27A	1.85	2.00	2.05	2.00	2.10	2.35	2.43	2.44	2.55	2.70	2.54	1.64
27B	1.63	1.81	1.84	1.78	1.88	2.17	2.24	2.21	2.38	2.56	2.31	1.02
30	0.44	0.51	0.60	0.63	0.75	1.07	0.89	1.01	1.13	1.37	0.47	
32	3.14	3.21	3.26	3.30	3.38	3.49	3.54	3.56	3.63	3.70	3.64	3.22
40	2.13	2.14	2.19	2.12	2.22	2.55	2.47	2.53	2.72	2.90	2.25	1.94
41	0.44	0.49	0.49	0.58	0.59	0.95	0.99	0.88	1.25	1.61	1.33	0.57
43	2.36	2.45	2.46	2.57	2.67	2.80	2.89	2.90	3.03	3.13	3.13	2.51
46	3.40	3.47	3.56	3.56	3.62	3.74	3.80	3.79	3.87	3.93	3.88	3.46
H1	1.48	1.70	1.76	1.70	1.86	Dry	Dry	Dry	Dry	Dry	Dry	1.04
H2	1.85	2.00	2.07	2.06	2.19	2.45	2.52	2.55	2.66	Dry	Dry	2.06
H3	1.94	2.14	2.25	2.24	2.45	2.78	Dry	Dry	Dry	Dry	Dry	1.97
H4	0.88	1.20	1.14	0.99	1.12	1.46	1.37	1.31	1.51	1.79	1.56	0.27
H5	0.70	0.92	0.94	0.81	0.95	1.22	1.17	1.11	1.31	1.55	1.02	0.39
H6	1.51	1.66	1.71	1.71	1.86	2.04	2.09	2.11	2.22	2.36	2.28	1.60
H7	1.66	1.82	1.88	1.79	1.92	2.14	2.18	2.24	2.28	2.48	2.43	1.79
H8	1.05	1.34	1.34	1.17	1.31	1.65	1.68	1.48	1.76	2.01	1.48	0.72

DEPTH of WATER below GROUND, m

Piezom. No.	16-Jun-88 32310	23-Aug-88 32378	22-Jul-89 32711	26-Aug-89 32746	09-Sep-89 32760	23-Sep-89 32774	07-Oct-89 32788	15-Oct-89 32796
4	3.37	3.34	3.27	3.34	3.29	3.18	3.25	3.28
5A	3.53	3.47	3.39	3.47	3.37	3.30	3.38	3.41
5B	2.45	2.15	1.83	1.92	1.81	1.69	1.84	1.93
7A	2.77	2.47	2.35	2.42	2.22	2.12	2.33	2.41
7B	3.03	2.85	2.73	2.87	2.65	2.52	2.68	2.76
9	3.48	3.33	3.27	3.36	3.17	3.10	3.24	3.30
24A	3.60	3.45	3.38	3.46	3.41	3.26	3.36	3.42
24B	3.52	3.48	3.41	3.46	3.40	3.31	3.38	3.41
25	0.77	0.62	0.53	0.59	0.50	0.34	0.49	0.56
26	0.85	0.75	0.73	0.71	0.65	0.65	0.69	0.74
27A	2.09	2.12	1.82	1.85	1.81	1.30	1.55	1.71
27B	1.85	1.74	1.66	1.74	1.69	1.07	1.40	1.57
30	0.64	0.83	0.71	0.75	0.69	0.55	0.62	0.67
32	3.35	3.19	3.11	3.18	3.08	2.92	3.08	3.14
40	2.17	2.27	2.19	2.18	2.15	1.92	2.10	2.21
41	0.82	0.68	0.52	0.50	0.44	0.35	0.50	1.11
43	2.63	2.34	2.21	2.30	2.23	1.95	2.18	2.29
46	3.60	3.44	3.36	3.44	3.37	3.18	3.33	3.41
H1	1.80	1.70	1.62	1.70	1.37	1.22	1.50	1.62
H2	2.16	1.95	1.90	2.05	1.57	1.67	1.87	1.97
H3	2.33	2.11	2.01	2.17	1.37	1.66	2.02	2.14
H4	0.95	1.17	1.09	1.08	0.11	0.48	0.61	0.76
H5	0.83	0.90	0.81	0.80	0.14	0.46	0.56	
H6	1.78	1.59	1.57	1.63	1.11	1.30	1.48	1.59
H7	1.82	1.70	1.63	1.70	1.15	1.44	1.60	1.70
H8	1.15	1.40	1.25	1.27	0.50	0.84	0.95	1.10

Piezom. No.		WL DEPTH, m MAX.	WL DEPTH, m MIN.	WL DEPTH, m RANGE	UNSATURATED, m MAX.	UNSATURATED, m MIN.	% UNSATURATED MAX.	% UNSATURATED MIN.
4	B	3.49	3.05	0.44	2.80	2.65	100%	95%
5A	B	3.74	3.19	0.55	1.28	1.28	100%	100%
5B	B	2.93	1.69	1.24	1.28	1.28	100%	100%
7A	T	3.13	2.12	1.01	2.73	1.72	57%	36%
7B	B	3.42	2.49	0.93	3.02	2.09	63%	44%
9	B	3.80	2.98	0.82	3.40	2.58	82%	62%
24A	B	3.95	3.25	0.70	1.73	1.73	100%	100%
24B	B	3.75	3.09	0.66	1.73	1.73	100%	100%
25	B	1.12	0.28	0.84	0.72	0.00	42%	0%
26	B	1.07	0.63	0.44	0.67	0.23	25%	9%
27A	T	2.70	1.30	1.40	2.30	0.90	48%	19%
27B	T	2.56	1.02	1.54	2.16	0.62	52%	15%
30	B	1.37	0.32	1.05	0.97	0.00	48%	0%
32	B	3.70	2.81	0.89	2.34	2.34	100%	100%
40	B	2.90	1.80	1.10	2.50	1.40	65%	36%
41	B	1.61	0.34	1.27	1.21	0.00	37%	0%
43	B	3.13	1.95	1.18	2.73	1.55	66%	37%
46	B	3.93	3.08	0.85	3.53	2.68	85%	64%
H1	T	1.98	0.56	1.42	1.58	0.16	93%	9%
H2	T	2.74	1.57	1.17	2.34	1.17	96%	48%
H3	T	2.77	1.08	1.69	2.37	0.68	95%	27%
H4	T	1.79	0.11	1.68	1.39	0.00	76%	0%
H5	T	1.55	0.14	1.41	1.15	0.00	57%	0%
H6	T	2.36	1.11	1.25	1.96	0.71	93%	34%
H7	T	2.48	1.15	1.33	2.08	0.75	84%	30%
H8	T	2.01	0.50	1.51	1.61	0.10	87%	6%

H1-H3 go DRY. M27 and H1-H8 have TD in TAILINGS

PIEZOMETER BOTTOM TEMPERATURES and SNOW DEPTHS

Piezometer No.		Coordinates (ft) Northing	Easting	Stick-up m	Depth Collar to Tip m	Tip below Ground m	'Aquifer' Material	Temp., C 01-Apr-87 31868	18-Jul-87 31976	Temp. Difference C	Snow Depth, cm 02-Jan-87 31779	08-Feb-87 31816	15-Mar-87 31851
02	B	16865	12500	0.92	2.78	1.86	Fill/Sand	2.9	14.5	11.6	40.6	35.6	43.2
04	B	16380	11130	0.50	5.68	5.18	Sand	6.3	12.5	6.2	38.1	48.3	30.5
05A	B	16020	11020	0.46	11.28	10.82	Coarse Sand	7.0	11.8	4.8	43.2	45.7	38.1
05B	B	16020	11020	0.47	5.80	5.33	Coarse Sand	7.2	11.5	4.3	43.2	45.7	38.1
07A	T	15810	12505	0.45	5.29	4.85	TAILINGS	6.2	14.0	7.8	55.9	71.1	1.0
07B	B	15810	12505	0.21	10.76	10.55	Sand	6.7	12.7	6.0	55.9	71.1	45.7
09	B	15250	11885	0.52	6.95	6.43	Sand/Gravel	6.4	10.9	4.5	40.6	43.2	35.6
24A	B	15300	11080	0.35	8.61	8.26	Sand	6.2	10.5	4.3	48.3	48.3	45.7
24B	B	15300	11080	0.39	5.75	5.36	Sand	5.8	11.8	6.0	48.3	48.3	45.7
25	B	16000	12485	0.54	5.23	4.69	Sand	7.0	11.3	4.3	63.5	58.4	45.7
26	B	15940	12120	0.45	5.94	5.49	Sand	6.1	12.0	5.9	45.7	45.7	50.8
27A	T	15750	11085	0.65	5.65	5.00	TAILINGS	5.8	11.9	6.1	50.8	53.3	45.7
27B	T	15750	11085	0.49	4.94	4.45	TAILINGS	5.4	11.8	6.4	50.8	53.3	45.7
30	B	16435	11700	0.49	4.48	3.99	Sand	5.3	11.9	6.6	45.7	48.3	45.7
31	B	16900	13080	0.44	6.57	6.13	Sand	5.8	9.9	4.1	43.2	45.7	30.5
32	B	15500	12150	0.31	10.70	10.39	Bedrock	6.5	9.4	2.9	53.3	58.4	50.8
40	B	15890	11730	0.65	6.99	6.34	Sand/Bedrock	6.4	9.6	3.2	50.8	48.3	38.1
41	B	16075	11410	0.78	5.69	4.91	Sand	5.9	12.6	6.7	48.3	58.4	40.6
43	B	15690	12360	0.23	9.59	9.36	Fine Sand	7.0	10.0	3.0	58.4	48.3	48.3
46	B	15370	12020	0.52	11.77	11.25	Bedrock	6.2	9.3	3.1	40.6	45.7	38.1
H01	T	15300	11705	0.39	2.49	2.10	TAILINGS	2.8	17.0	14.2	45.7	58.4	53.3
H02	T	15220	11360	0.53	3.40	2.87	TAILINGS	4.3	15.8	11.5	40.6	40.6	40.6
H03	T	15310	11225	0.29	3.19	2.90	TAILINGS	4.2	14.0	9.8	45.7	45.7	38.1
H04	T	15400	11485	0.60	2.83	2.23	TAILINGS	2.8	15.0	12.2	45.7	53.3	45.7
H05	T	15445	11730	0.63	3.04	2.41	TAILINGS	3.1	14.9	11.8	40.6	61.0	53.3
H06	T	15505	11955	0.29	2.79	2.50	TAILINGS	3.8	16.5	12.7	45.7	48.3	45.7
H07	T	15645	12020	0.43	3.33	2.90	TAILINGS	4.8	16.6	11.8	35.6	33.0	25.4
H08	T	15490	11580	0.48	2.73	2.26	TAILINGS	3.5	14.4	10.9	30.5	43.2	38.1

SUBSURFACE TEMPERATURES (degrees C) from THERMISTOR STRING IN TAILINGS

LOCATION: Northing - 16175 Easting - 10965

Depth, cm	0.00	10.16	22.86	38.10	60.96	91.44	121.92	152.40	182.88	213.36	243.84
31-Oct-86	-2.5	4.0	6.4	6.4	8.3	9.9	10.8	13.1	13.1	13.6	13.3
03-Nov-86	-5.2	-3.2	1.7	4.3	7.1	8.8	10.3	12.2	12.1	12.7	13.2
04-Nov-86	-4.1	-3.8	-1.3	2.5	6.5	8.6	9.4	10.8	11.7	12.3	12.6
05-Nov-86	2.1	1.5	1.1	2.4	5.3	7.2	9.4	10.1	11.7	12.6	12.3
17-Nov-86	-1.5	1.6	2.2	3.8	4.8	7.6	7.7	9.1	11.2	11.6	12.7
22-Nov-86	1.3	2.1	1.8	3.5	4.6	6.3	8.3	8.4	10.6	11.6	12.3
30-Nov-86	0.6	1.9	3.1	4.7	6.0	6.8	8.0	8.6	10.0	11.1	11.6
07-Dec-86	0.0	1.9	3.1	4.2	5.4	6.8	7.7	7.7	10.0	10.5	11.0
14-Dec-86	2.0	3.2	4.3	5.2	6.3	7.2	7.4	9.3	9.0	10.9	12.0
21-Dec-86	1.5	1.8	2.6	4.1	5.2	6.1	6.5	7.4	8.6	9.0	9.8
28-Dec-86	1.3	2.0	2.5	3.7	5.1	5.8	6.3	7.4	8.5	9.0	9.2
04-Jan-87	0.6	1.0	1.7	2.8	3.9	5.5	6.0	7.3	7.8	8.2	8.6
11-Jan-87	1.3	1.6	2.5	3.5	4.6	5.5	6.4	6.8	7.8	8.3	8.8
24-Jan-87	-5.4	-4.5	1.8	1.7	3.8	5.1	6.7	7.1	8.1	10.2	10.7
08-Feb-87	-0.8	0.6	1.0	1.9	3.5	4.0	5.0	6.1	7.0	7.6	8.3
15-Feb-87	0.8	1.5	2.6	3.5	4.3	5.2	6.3	7.2	8.3	8.5	8.7
22-Feb-87	0.3	1.1	1.0	1.8	2.6	3.7	4.5	4.5	5.4	6.0	7.0
01-Mar-87	0.3	1.8	2.5	3.2	3.3	3.4	3.8	4.3	5.1	5.8	6.4
15-Mar-87	2.3	1.3	1.2	1.8	3.5	4.7	5.3	5.6	6.5	7.2	7.6
29-Mar-87	0.3	1.3	2.1	3.8	4.6	5.0	5.1	6.0	6.8	7.0	7.7
10-Apr-87	14.5	10.5	8.9	8.6	6.8	5.0	4.2	4.8	4.9	5.6	5.8
15-Apr-87	19.0	13.2	10.0	8.2	7.1	6.1	5.5	4.7	4.5	4.4	4.8
29-Apr-87	17.3	13.3	11.7	11.5	11.3	10.5	9.6	9.1	8.3	8.0	8.1
06-May-87	17.6	17.1	15.4	15.3	14.6	12.1	10.6	10.0	8.8	7.9	7.8
14-May-87	12.0	12.5	13.7	15.3	15.8	14.2	13.0	12.1	10.5	9.7	9.1
23-May-87	17.8	14.5	12.3	12.7	13.2	12.9	12.9	12.5	11.3	10.5	9.6
01-Jun-87	23.0	20.3	18.1	17.0	17.1	16.4	15.3	13.8	12.1	11.0	10.2
14-Jun-87	26.3	23.7	22.2	21.7	20.0	17.3	16.0	15.3	13.3	12.2	11.0
20-Jun-87	32.5	29.1	26.0	24.6	22.7	20.1	17.4	15.8	13.1	11.8	10.7
28-Jun-87	24.3	25.3	23.9	22.6	22.2	21.4	20.0	18.6	16.0	14.2	12.8
05-Jul-87	29.5	27.1	24.4	23.6	22.0	19.7	18.2	17.2	15.3	14.1	12.7
18-Jul-87	22.1	24.0	23.5	22.8	22.1	20.5	19.3	18.6	17.1	15.9	14.8
15-Aug-87	31.2	30.4	26.2	24.2	23.1	22.0	21.3	20.8	19.3	18.3	17.4
25-Sep-87	14.7	12.6	13.6	16.3	18.4	18.7	18.8	18.5	17.8	17.2	17.4
06-Oct-87	6.3	7.3	9.0	11.3	14.6	16.3	17.0	17.7	17.3	17.9	17.3
12-Nov-87	-0.2	3.6	3.9	5.1	6.7	7.8	12.5	9.8	11.7	12.3	13.7
14-Dec-87	-3.8	1.1	1.9	3.2	4.7	6.0	8.6	7.8	9.1	9.9	10.8
17-Jan-88	-4.7	-0.6	0.2	1.3	3.1	5.1	7.0	7.6	9.1	10.1	10.7
14-Apr-88	1.3	2.4	2.6	3.0	3.7	3.9	4.0	4.4	5.0	5.5	6.0
25-Apr-88	7.5	5.7	5.7	6.6	6.1	5.5	4.8	4.6	4.8	5.1	5.8
16-Jun-88	22.7	22.1	21.8	22.9	23.5	23.0	22.3	21.5	19.5	18.7	17.7
10-Jun-89	26.3	27.6	24.7	21.1	18.0	15.8	14.3	13.3	11.7	10.8	9.8
24-Jun-89	31.7	22.8	20.7	20.1	20.0	19.0	17.5	16.3	14.2	12.8	11.7
08-Jul-89	30.4	29.2	26.5	24.6	23.6	22.3	20.6	19.0	16.9	15.1	13.9
22-Jul-89	38.1	32.6	29.8	27.8	25.8	23.4	21.3	19.8	17.5	16.0	14.6
26-Aug-89	24.1	24.0	23.3	23.3	23.1	22.0	21.0	20.2	18.9	17.9	17.0
09-Sep-89	16.5	15.7	16.2	17.5	19.5	20.2	20.3	20.1	19.2	18.2	17.7
23-Sep-89	12.7	9.9	9.6	11.5	15.2	18.1	18.2	18.1	18.0	17.5	16.8
07-Oct-89	9.7	7.5	6.8	8.1	10.7	13.1	14.8	15.0	15.5	15.8	15.7
15-Oct-89	2.5	4.5	6.1	8.1	10.8	12.4	13.1	13.7	14.7	15.1	15.3
MAX	38.1	32.6	29.8	27.8	25.8	23.4	22.3	21.5	19.5	18.7	17.7
MIN	-5.4	-4.5	-1.3	1.3	2.6	3.4	3.8	4.3	4.5	4.4	4.8
RANGE	43.5	37.1	31.1	26.5	23.2	20.0	18.5	17.2	15.0	14.3	12.9

MONTHLY PRECIPITATION (mm) at EAR FALLS (ONTARIO), 1971-1989

Location : 50X38'N 93X13'W
Elevation: 361 m

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1971	18.8	22.1	52.1	75.4	23.4	81.0	107.7	20.8	100.6	83.1	40.4	NA	625.4 X
1972	35.6	NA	NA	NA	25.4	32.3	114.0	87.6	134.6	49.3	31.8	53.3	563.9 X
1973	4.1	33.3	2.0	48.5	26.9	107.7	70.6	171.7	112.5	68.1	72.1	16.5	734.0
1974	30.0	14.0	42.7	103.1	118.6	104.9	89.2	182.9	53.3	29.0	27.4	20.3	815.4
1975	79.0	26.2	47.0	33.6	74.9	119.9	104.6	129.3	74.9	64.5	18.3	43.2	815.4
1976	42.7	25.7	43.2	60.7	10.4	128.0	60.2	39.4	42.4	36.1	18.3	26.2	533.3
1977	21.2	44.5	20.3	9.4	84.9	116.7	132.0	103.0	107.1	22.7	68.5	25.5	755.8
1978	18.1	5.7	18.5	15.2	53.9	101.6	151.3	96.4	52.4	22.2	50.7	34.2	620.2
1979	10.5	34.0	60.0	52.0	68.1	61.4	70.1	195.5	33.9	91.5	36.5	31.0	744.5
1980	40.1	20.3	24.5	15.5	50.2	70.2	51.2	131.5	111.7	30.1	13.0	20.0	578.3
1981	22.0	3.8	18.5	27.5	18.1	117.8	48.8	92.8	NA	34.6	24.8	NA	408.7 X
1982	17.5	33.5	30.0	34.0	101.3	68.7	93.7	70.9	90.3	82.0	3.0	12.0	636.9
1983	39.5	24.5	81.0	1.0	54.9	136.9	92.5	63.7	86.7	28.2	65.0	27.5	701.4
1984	25.5	10.0	21.0	35.3	110.7	127.7	86.5	76.3	47.7	149.7	14.7	54.2	759.3
1985	48.4	31.0	11.5	38.6	89.7	166.2	39.6	143.8	99.7	30.8	33.2	27.0	759.5
1986	25.5	22.6	41.5	72.7	28.2	52.6	67.9	76.7	141.7	20.7	33.0	27.0	610.1
1987	11.0	24.0	26.2	6.6	68.0	69.8	88.9	64.9	26.0	23.5	20.7	22.0	451.6
1988	28.2	28.2	60.0	1.0	34.6	92.5	156.6	115.6	121.3	56.7	81.6	51.2	827.5
1989	25.0	10.0	12.0	13.6	67.0	101.4	51.3	129.4	30.8	19.5			460.0 X
MEAN	28.6	23.0	34.0	35.8	58.4	97.8	88.2	104.9	81.5	49.6	36.3	30.7	675.2 X
MAX	79.0	44.5	81.0	103.1	118.6	166.2	156.6	195.5	141.7	149.7	81.6	54.2	827.5
MIN	4.1	3.8	2.0	1.0	10.4	32.3	39.6	20.8	26.0	19.5	3.0	12.0	451.6 X

NA - Not Available X - Incomplete Data

Ear Falls, Ontario - CLIMATE NORMALS, 1951-1980

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Precipitation, mm													Totals
Rain	0	0	3.5	22.7	53.6	89.3	95.4	91.4	68.4	43.6	6.3	1.5	475.7
Snow	33.2	27.1	26	17.3	3.7	0.3	0	0	1.4	7.6	36.5	32.9	186.0
MEAN P	33.2	27.1	29.5	40.0	57.3	89.6	95.4	91.4	69.8	51.2	42.8	34.4	661.7
Temperature, degree C													Means
MAX T	-14.2	-9.3	-1.8	7.6	15.5	21.1	24.2	22.5	15.7	8.9	-1.8	-10.5	6.5
MIN T	-23.7	-20.7	-13.6	-3.9	2.9	9.2	12.3	11.1	6.1	0.7	-8.5	-18.9	-3.9
MEAN T	-19.0	-15.0	-7.7	1.8	9.2	15.2	18.3	16.8	10.9	4.8	-5.2	-14.7	1.3

ESTIMATES for the SOUTH BAY SITE

Mean Annual Precipitation	675 mm		
Mean Annual Lake Evaporation	500 mm		
Mean Annual Evapotranspiration	400 mm		
Net Mean Annual precipitation	175	to	275 mm

ANALYSES OF WATER SAMPLES FROM PIEZOMETERS (mg/L)

PIEZOMETER #		M-4	M-4	M-5a	M-5a	M-5b	M-5b	M-7a	M-7a	M-7a	M-7b
Setting		B	B	B	B	B	B	T	T	T	B
Northing		16380	16380	16020	16020	16020	16020	15810	15810	15810	15810
Easting		11130	11130	11020	11020	11020	11020	12505	12505	12505	12505
Day/Mo/Yr		06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	19/07/87	12/04/88	06/11/86
Temp C		6.5		8		10		8			7.5
pH, Fld		5.8	4.68	6.4	5.87	6.8	6.06	5.6	5.3	3.63	6.3
pH, lab		4.55	3.82	5.85	5.71	6.2	5.89	3.9		3.63	5.7
Cond.,Fld		2850		900		2100		110	13500		6000
Cond.,lab			2200		2450		3050			11000	
Acidity		3958		231		405		30120			9460
Element	At.Weight										
Ag	107.8680	<0.005	<0.01	0.03	<0.01	0.06	<0.01	<0.005	<0.005	0.02	<0.005
Al	26.9815	1.7	5	0.68	0.3	0.81	0.4	11	0.12	5.3	1.4
As	74.9216	3.3	0.05	1.9	0.01	3.1	0.01	5	0.6	0.08	4
B	10.8100	0.59	1	0.09	1	0.15	1	10	0.34	6	2.7
Ba	137.3300	<0.005	0.03	<0.005	0.03	0.008	0.03	0.02	<0.005	0.04	<0.005
Be	9.0122	<0.005	<0.01	<0.005	<0.01	<0.005	<0.01	0.29	0.07	0.01	0.02
Bi	208.9804	0.57	0.1	0.07	0.03	0.31	0.06	3.8	0.8	2	1.5
C	12.0110	408	1275	441	1675	1589	2239	611	1195	142	1717
Ca	40.0800	452	364	250	562	532	647	310	391	173	529
Cd	112.4100	0.08	0.06	0.06	0.02	0.05	0.05	0.47	0.2	0.1	0.18
Ce	140.1200	0.26	0.06	0.36	0.02	0.51	0.03	0.54	0.2	0.05	0.42
Co	58.9332	0.51	0.5	0.41	1.6	0.27	1	4.6	4.9	0.3	0.76
Cr	51.9960	0.13	0.1	0.06	0.06	0.09	0.08	0.57	0.4	0.3	0.3
Cu	63.5460	<0.005	0.05	0.07	0.02	0.09	0.04	0.11	0.4	0.1	0.005
Fe	55.8470	1009	644	66	511	148	1064	9857	#####	9938	3643
Hg	200.5900	0.64	<0.01	<0.01	<0.01	<0.01	<0.01	2.5	0.3	0.09	1.3
K	39.0983	31	28	19	16	22	12	46	54	24	36
La	138.9055	0.13	0.02	0.12	<0.01	0.13	<0.01	0.16	0.05	0.1	0.1
Mg	24.3050	163	189	55	178	134	224	456	407	189	364
Mn	54.9380	35	23	12	50	10	30	187	2.07	101	128
Mo	95.9400	<0.01	0.1	0.11	0.1	0.02	0.1	1.8	0.2	0.7	0.53
Na	22.9898	15	22	10	34	14	19	10	9.9	3	32
Nb	92.9064	0.28	0.04	0.21	<0.01	0.28	<0.01	2	0.4	0.6	1
Ni	58.7000	0.26	0.2	0.26	0.6	0.18	0.3	2	2.3	0.9	0.45
P	30.9738	0.8	<0.01	0.54	1	0.44	<0.01	15	1.6	7	3.8
Pb	207.2000	0.86	0.4	0.34	0.2	0.41	0.4	4.4	2.6	2	1.9
S	32.0600	1233	1249	327	1254	591	1616	5668	6735	3009	2459
Sb	121.7500	0.9	0.09	0.38	0.06	0.53	0.1	7	0.3	0.4	2
Se	78.9600	2.1	0.07	0.24	0.05	0.81	0.09	12	0.1	0.3	5.5
Si	28.0855	11	12	6	15	10	11	17	25	9	12
Sn	118.6900	0.5	<0.01	0.08	<0.01	0.23	<0.01	2.4	0.02	0.05	1.1
Sr	87.6200	0.67	0.9	0.3	1.2	0.4	1.3	0.8	0.36	0.4	0.93
Te	127.6000	1.2	0.1	0.81	0.1	1	0.1	11	1.3	0.5	2.8
Th	232.0381	0.66	0.6	0.32	0.3	0.57	0.9	5.5	1.1	4	2
Ti	47.9000	0.04	0.02	0.02	0.01	0.04	0.02	0.03	<0.005	0.04	0.04
U	238.0290	2.4	4	1.4	3	1.7	6	36	7.6	21	10
V	50.9415	0.05	0.03	0.04	0.02	0.07	0.03	0.14	0.2	0.06	0.1
W	183.8500	1.8	0.1	1.6	0.3	1.6	0.2	23	2.5	0.8	3.3
Y	88.9059	0.04	0.08	0.02	0.02	0.02	0.01	0.09	0.2	0.1	0.04
Zn	65.3800	60	45	61	162	57	132	629	761	347	91
Zr	91.2200	0.05	0.05	0.04	0.03	0.06	0.06	0.28	0.4	0.1	0.1
SUM, mg/L		3438	3865	1258	4467	3121	6006	17954	9610	13988	9059

PIEZOMETER	M-7b	M-7b	M-9	M-9	M-9	M-24A	M-24A	M-24B	M-24B	M-25	M-26
Setting	B	B	B	B	B	B	B	B	B	B	B
Northing	15810	15810	15250	15250	15250	15300	15300	15300	15300	16000	15940
Easting	12505	12505	11885	11885	11885	11080	11080	11080	11080	12485	12120
Day/Mo/Yr	19/07/87	12/04/88	06/11/86	19/07/87	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	06/11/86
Temp C			9			7		5		7.5	8
pH, Fld	5.9	5.15	5.8	5.4	5.6	5.1	3.47	5.7	3.1	6.8	6.8
pH, lab		4.61	4.3		5.16	3.65	3.33	4	3.34	6.55	6.5
Cond.,Fld	10400		5500	4700		6000		2850		410	750
Cond.,lab		8000			4150		6000		3700		
Acidity			9170			11920		6227		63.7	110
Element											
Ag	(0.005	0.02	(0.005	(0.005	(0.01	(0.005	0.01	(0.005	0.01	0.01	(0.005
Al	3.5	5.3	4.7	3.4	1.6	7.6	0.9	1.6	9	0.33	0.3
As	0.4	0.08	4	0.2	4.6	3	0.03	5.8	0.05	1.1	1.5
B	2.3	6	2.5	0.6	2	3.3	1	0.77	2.8	0.04	0.05
Ba	(0.005	0.04	0.006	(0.005	0.04	(0.005	0.02	(0.005	0.03	0.13	(0.005
Be	0.05	0.01	0.04	0.07	0.01	0.04	(0.01	(0.005	0.1	(0.005	(0.005
Bi	0.6	0.2	1.4	0.3	0.3	1.6	0.09	0.56	1	0.03	(0.005
C	3937	150	693	1205	524	375	140	617	777	1413	2508
Ca	482	169	396	485	342	278	128	282	386	98	133
Cd	0.07	0.1	0.19	(0.005	0.1	0.22	0.06	0.12	0.4	0.02	0.01
Ce	0.2	0.02	0.77	0.3	0.05	2.6	0.07	0.24	1	0.1	0.1
Co	1.8	1.1	1	0.1	0.3	0.36	0.9	0.4	0.4	0.008	0.01
Cr	0.3	0.3	0.28	0.03	0.1	0.28	0.1	0.15	0.1	0.02	0.02
Cu	0.2	0.2	0.02	0.2	0.09	(0.005	0.06	(0.005	2	0.04	0.03
Fe	#####	6810	3436	#####	2144	4433	4879	1229	1560	1	11
Hg	0.2	0.09	1.3	0.01	(0.01	1.2	(0.01	0.62	0.06	(0.01	(0.01
K	71	24	38	81	29	29	24	27	24	17	16
La	0.05	0.1	0.26	0.07	(0.01	1.4	0.02	0.13	0.04	0.03	0.03
Mg	532	189	176	227	157	229	75	99	90	19	15
Mn	194	100	44	28	24	63	28	39	37	0.59	0.97
Mo	0.1	0.7	0.53	0.2	(0.01	0.57	0.3	0.31	0.2	(0.01	0.02
Na	42	3	9	45	28	9	7	5	7	24	23
Nb	0.3	0.6	0.61	0.1	0.05	0.6	(0.01	0.26	0.06	0.04	0.05
Ni	1.2	0.9	0.57	0.9	0.3	0.51	0.3	0.22	0.4	0.07	0.04
P	1.2	7	4	0.7	2	4.9	(0.01	1.2	4.6	0.09	0.18
Pb	2	1.9	1.9	0.7	0.7	1.9	0.4	0.97	0.7	0.12	0.2
S	5193	2969	2197	2048	1589	2761	864	1251	1749	32	29
Sb	0.2	0.4	2.5	0.05	0.1	2.8	0.1	0.91	2	0.16	0.2
Se	0.1	0.3	5.3	0.5	0.1	6.3	0.07	2.8	1	(0.005	0.19
Si	19	9	13	11	7	13	3	13	16	8.3	12
Sn	0.2	0.05	1.1	0.1	0.02	1.3	(0.01	0.48	0.02	(0.01	0.15
Sr	1.1	4	0.46	0.8	0.9	0.72	0.3	0.15	0.6	0.1	0.15
Te	0.08	5	4.5	0.4	0.2	5	0.2	2.3	2	0.12	0.12
Th	1.1	4	1.8	0.5	2.1	2	0.2	0.62	2	0.12	0.09
Ti	(0.005	0.2	0.05	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01
U	5.8	21	10	2.1	9	0.13	5	3.7	10	0.71	0.69
V	0.2	0.06	0.11	0.2	0.04	0.06	0.04	0.04	0.03	0.01	0.01
W	0.8	0.8	8.11	0.3	2	9.2	0.5	4.6	3	0.13	0.09
Y	0.04	0.1	0.06	0.04	0.02	0.36	0.05	0.03	0.1	0.01	0.009
Zn	267	345	273	59	83	310	232	171	144	0.78	0.57
Zr	0.4	0.1	0.13	0.3	0.09	0.12	0.07	0.04	0.09	0.03	0.02
SUM, mg/L	10761	10829	7333	4202	4954	8558	6391	3762	4834	1617	2753

PIEZOMETER	M-26	M-27A	M-27A	M-27B	M-27B	M-30	M-30	M-32	M-32	M-32	M-40
Setting	B	T	T	T	T	B	B	B	B	B	B
Northing	15940	15750	15750	15750	15750	16435	16435	15500	15500	15500	15890
Easting	12120	11085	11085	11085	11085	11700	11700	12150	12150	12150	11730
Day/Mo/Yr	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	19/07/87	12/04/88	06/11/86
Temp C		7		7		6		7			6
pH, Fld	6.37	7.1	6.63	6.6	5.84	6.6	6.61	5.85	5.7/5.8	5.88	6.5
pH, lab	6.28	7.05	6.28	6.1	6.2	6.55	6.65	5.05		5.57	6
Cond.,Fld		350		950		115		3400	2910		2450
Cond.,lab	800		700		1300		160			2500	
Acidity		17.3		57.9		13.5		4779			453
Element											
Ag	(0.01	0.01	(0.01	0.02	(0.01	0.03	(0.01	(0.005	(0.005	0.01	0.14
Al	0.5	0.35	0.4	0.44	0.4	0.44	0.3	2.3	9.4	0.7	0.9
As	0.04	1	0.03	1.3	0.04	0.77	(0.01	3.8	0.1	0.05	3.4
B	0.1	0.01	0.1	0.05	0.1	0.01	0.1	0.67	0.3	1.4	0.15
Ba	0.04	(0.005	0.04	(0.005	0.05	(0.005	0.02	(0.005	(0.005	0.05	0.02
Be	(0.01	0.007	(0.01	(0.005	0.01	(0.005	(0.01	(0.005	(0.005	(0.01	(0.005
Bi	0.2	0.02	0.04	(0.005	0.07	0.05	(0.01	0.58	0.2	0.1	0.25
C	2095	681	847	365	323	283	113	1449	2251	962	1017
Ca	163	65	150	189	332	28	36	385	370	341	710
Cd	0.03	0.02	0.01	0.02	0.03	0.02	(0.01	0.24	(0.005	0.04	0.05
Ce	0.04	0.16	(0.01	0.12	0.01	0.13	(0.01	1.3	0.4	0.05	0.6
Co	0.1	0.03	0.09	0.02	0.1	0.03	(0.01	1.5	0.4	0.5	0.04
Cr	0.07	0.01	0.03	0.03	0.05	0.03	(0.01	0.15	0.03	0.1	0.12
Cu	0.04	0.05	0.02	0.07	0.05	0.03	(0.01	(0.005	0.9	0.09	0.09
Fe	28	0.44	12	16	2.6	0.36	21	1139	xxxxx	927	147
Hg	(0.01	(0.01	(0.01	(0.01	(0.01	(0.01	(0.01	0.67	0.008	(0.01	(0.01
K	22	22	32	26	42	13	6	22	73	19	47
La	(0.01	0.01	(0.01	0.03	(0.01	0.07	(0.01	0.62	0.09	(0.01	0.12
Mg	27	3.4	19	16	76	3.4	6.1	135	133	113	142
Mn	1.6	0.42	1.7	1.6	0.8	0.47	0.8	60	35	34	5.8
Mo	0.01	0.04	(0.01	(0.01	(0.01	0.02	(0.01	0.52	0.08	0.1	0.02
Na	37	43	70	38	73	6.6	5	14	34	24	36
Nb	0.02	0.06	(0.01	0.08	(0.01	0.07	(0.01	0.44	0.1	(0.01	0.27
Ni	0.04	0.05	0.02	0.07	0.04	0.07	0.07	0.38	0.6	0.2	0.14
P	2.8	0.05	(0.01	0.06	(0.01	0.07	0.1	2	0.6	3	0.7
Pb	0.1	0.19	0.1	0.27	0.1	0.28	0.01	0.98	0.5	0.4	0.52
S	99	44	211	181	542	12	56	1401	1252	1035	802
Sb	0.03	0.25	(0.01	0.3	(0.01	0.2	(0.01	1	0.1	0.1	0.6
Se	0.02	(0.005	(0.01	0.16	(0.01	0.19	(0.01	2.8	0.04	0.06	0.8
Si	11	3.7	(0.01	3.5	0.7	6.3	6	10	11	9	9
Sn	0.01	(0.01	(0.01	0.012	(0.01	(0.01	(0.01	0.49	0.007	(0.01	0.23
Sr	0.3	0.08	1.4	0.22	1	0.05	0.1	0.47	0.3	0.8	0.37
Te	0.06	0.11	(0.01	0.12	(0.01	0.11	(0.01	3.2	0.04	0.06	0.62
Th	0.2	0.09	(0.01	0.14	(0.01	0.13	(0.01	0.71	0.3	0.1	0.62
Ti	0.01	0.01	0.01	0.02	0.01	0.02	(0.01	0.03	0.02	0.01	0.05
U	1.1	0.81	0.5	1	1	1	(0.01	3	1.8	5	1.5
V	0.01	0.02	0.02	0.03	3	0.03	0.01	0.06	0.2	0.04	0.08
W	0.02	0.13	(0.01	0.2	(0.01	0.14	(0.01	7.9	0.03	0.1	0.6
Y	(0.01	0.01	(0.01	0.01	(0.01	0.01	(0.01	0.19	0.07	(0.01	0.03
Zn	2.5	0.39	1.9	3.9	4	0.33	2.7	285	110	56	12
Zr	0.01	0.02	0.02	0.03	0.03	0.03	(0.01	0.04	0.3	0.07	0.06
SUM, mg/L	2492	867	1347	845	1402	357	253	4936	4286	3533	2941

PIEZOMETER	M-40	M-41	M-41	M-43	M-43	M-46	M-46	M-46	H1	H1	H2
Setting	B	B	B	B	B	B	B	B	T	T	T
Northing	15890	16075	16075	15690	15690	15370	15370	15370	15300	15300	15220
Easting	11730	11410	11410	12360	12360	12020	12020	12020	11705	11705	11360
Day/Mo/Yr	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	19/07/87	12/04/88	15-Oct-86	06-Nov-86	15-Oct-86
Temp C		6		8		7			8	5.5	8
pH, Fld	2.61	6.4	6.08	5.8	2.85	6.1	5/5.1	5.7	6	6.65	6.1
pH, lab	2.83	6.2	6.09	4.65	3.11	5.7		5.21	6.14		5.9
Cond.,Fld		550		6000		3600	4000		2100	1750	4000
Cond.,lab	2800		950		7500			3200			
Acidity		104		10958		4634			1632	714	7480
Element											
Ag	(0.01	0.14	(0.01	(0.005	0.01	(0.005	(0.005	(0.01	(.005	(.005	(.005
Al	1.6	1	0.2	2.1	1.2	0.93	3.7	0.6	0.31	0.29	1.5
As	0.05	2.5	(0.01	3.1	(0.01	2.4	(0.01	0.06	0.5	2.1	4.7
B	1	0.07	0.2	3.3	3	0.7	3.9	2	0.29	0.13	2.34
Ba	0.05	0.02	0.06	0.01	0.02	(0.005	(0.005	0.03	0.02	(.005	0.006
Be	(0.01	(0.005	(0.01	0.02	(0.01	(0.005	(0.005	(0.01	(.005	(.005	0.05
Bi	0.4	0.43	0.01	1.5	0.1	0.55	0.1	0.1	0.02	(.005	1
C	212	2293	3197	890	65	972	935	825	53	164	195
Ca	521	110	214	365	224	467	485	660	547	480	392
Cd	0.07	0.06	(0.01	0.2	0.04	0.08	(0.005	0.09	(.005	0.01	0.11
Ce	0.05	0.8	0.02	0.2	(0.01	(0.005	0.3	0.04	(.005	0.08	(.005
Co	0.1	0.03	0.03	2	1.1	0.69	0.03	0.6	(.005	0.01	0.18
Cr	0.1	0.12	0.01	0.28	0.1	0.15	(0.005	0.1	0.02	0.03	0.09
Cu	0.07	0.11	(0.01	(0.005	0.1	(0.005	0.5	0.05	0.008	0.01	(.005
Fe	548	14	17	4175	4786	1180	#####	1304	267	309	1770
Hg	(0.01	(0.01	(0.01	1.3	(0.01	0.52	0.02	(0.01	(.01	(.01	0.27
K	37	33	23	39	23	21	73	23	16	15	7
La	(0.01	0.17	(0.01	0.16	0.09	0.1	0.09	(0.01	(.005	0.01	(.005
Mg	207	13	39	222	139	175	152	173	45	47	72
Mn	15	0.67	1.8	82	54	46	34	45	11	8	32
Mo	0.02	0.04	0.01	0.57	0.3	0.32	(0.01	0.2	0.04	(.01	0.32
Na	27	18	52	12	8	22	43	42	6.4	8	5.2
Nb	0.04	0.31	(0.01	0.71	(0.01	0.27	0.1	0.06	0.04	(.01	0.26
Ni	0.1	0.2	0.02	0.61	0.5	0.21	0.6	0.4	0.09	0.1	0.22
P	3.6	1.6	0.3	4.9	3	1	(0.01	1	(.01	(.01	1
Pb	0.3	0.53	0.05	1.8	0.9	0.93	0.4	0.5	0.03	0.15	0.77
S	1321	20	137	2600	2030	1434	1531	2028	621	607	1336
Sb	0.09	0.75	(0.01	2.7	0.2	0.91	0.1	0.1	0.1	0.06	1.2
Se	0.06	0.62	(0.01	6.5	0.1	3	0.3	0.1	0.07	0.59	2.5
Si	12	15	16	13	6	0.1	10	10	1.6	1.5	15
Sn	0.01	0.21	(0.01	1.2	0.02	44	0.04	0.01	0.02	0.06	0.41
Sr	1.2	0.08	0.5	0.67	0.6	0.66	0.5	1.4	0.87	0.82	0.39
Te	0.1	0.56	(0.01	4.7	0.3	2.2	0.3	0.1	(.005	0.07	1.4
Th	1.5	0.47	0.1	2	2	0.65	0.3	1	0.19	0.1	1.2
Ti	0.01	0.04	(0.01	0.02	(0.01	0.02	0.01	0.02	0.01	0.01	0.01
U	4.5	3.1	0.5	12	12	2.5	1.7	8	(.1	(.01	5.7
V	0.02	0.09	0.01	0.06	0.03	0.04	0.2	0.03	(.005	0.01	0.01
W	1	0.44	0.01	9.3	0.5	5	0.3	0.23	0.04	0.17	1.2
Y	0.02	0.03	(0.01	0.05	0.02	0.04	0.06	0.03	0.005	0.008	0.01
Zn	46	0.72	3	312	226	187	98	602	47	2.1	67
Zr	0.04	0.09	0.01	0.1	0.1	0.03	0.3	0.07	0.02	0.01	0.04
SUM, mg/L	2962	2532	3702	8772	7587	4572	3375	5729	1618	1646	3918

PIEZOMETER	H2	H3	H4	H4	H5	H5	H5	H6	H6	H7	H8
Setting	T	T	T	T	T	T	T	T	T	T	T
Northing	15220	15310	15400	15400	15445	15445	15445	15505	15505	15645	15490
Easting	11360	11225	11485	11485	11730	11730	11730	11955	11955	12020	11580
Day/Mo/Yr	08-Nov-86	08-Nov-86	08-Nov-86	12-Apr-88	06-Nov-86	02-Apr-87	12-Apr-88	15-Oct-86	06-Nov-86	07-Nov-86	15-Oct-86
Temp C	4.5	3.5	4		5.5			8	10	10	8
pH, Fld	6.1	6.1	6.3	6.76	6.6	6.2	4.22	6	5.8	6.1	5
pH, lab	4.8	5.66	6.4					6.1			4.45
Cond.,Fld	3200	3250	800		1400	1950		6000	4900	2800	11000
Cond.,lab											
Acidity	19570	2127	133		231			11152	7240	4055	33728
Element	CONC.,mg/l										
Ag	<.005	0.02	0.1	<.01	<.005	<.005	<.01	<.005	<.005	<.005	<.005
Al	2.5	1.2	0.85	2	0.24	0.8	1	0.92	0.86	1.41	9.9
As	1	1.6	1.2	<.01	1.3	5.3	<.01	6.9	2.9	4.8	16
B	0.4	0.2	0.04	0.1	0.09	<.005	0.8	3.3	1.4	0.56	9.2
Ba	<.005	<.005	<.005	0.03	<.005	0.03	0.03	0.01	<.005	<.005	0.04
Be	<.005	<.005	0.008	<.01	<.005	0.06	<.01	0.1	<.005	<.005	0.34
Bi	0.3	0.2	0.4	<.01	<.005	0.1	<.01	1.4	0.83	0.35	3.9
C	195	207	86	105	129	259	138	83	194	476	51
Ca	438	458	161	139	372	864	671	384	376	426	306
Cd	0.04	0.08	0.06	0.04	0.008	0.05	0.03	0.14	0.11	0.06	0.4
Ce	0.51	0.48	0.73	<.01	0.08	0.3	<.01	<.005	0.08	0.17	1.4
Co	0.05	0.03	0.05	0.1	.005	<.005	0.1	0.4	0.18	0.08	1.4
Cr	0.06	0.08	0.1	0.06	<.005	<.005	0.06	0.14	0.17	0.09	0.3
Cu	0.14	0.04	0.12	0.3	0.03	<.005	0.1	0.01	<.005	<.005	0.1
Fe	1896	822	31	8	59	137	214	2721	2848	950	6873
Hg	<.01	0.04	0.14	<.01	<.01	<.01	<.01	0.85	0.6	0.3	1.8
K	27	25	41	48	35	38	43	15	15	13	14
La	0.13	0.1	0.08	<.01	<.01	0.07	<.01	<.005	0.02	0.04	0.74
Mg	75	48	23	22	53	57.8	205	248	225	125	239
Mn	31	20	4.2	1	5	7.8	15	63	59	27	78
Mo	0.2	<.01	0.04	0.1	<.01	<.01	0.1	0.38	0.2	0.18	2
Na	5	5	52	80	56	51.4	64	16	15	14	11
Nb	0.37	0.27	0.25	<.01	<.01	0.28	<.01	0.57	0.31	0.16	1.1
Ni	0.28	0.2	0.21	0.08	0.02	0.04	0.2	0.38	0.2	0.09	1
P	0.9	0.31	0.79	<.01	0.1	2.7	<.01	1.9	1.8	1.2	10
Pb	0.42	0.36	0.38	0.1	0.14	<.01	0.3	1	1.3	0.75	2.8
S	1453	831	176	301	417	826	1497	1840	1864	1269	3878
Sb	0.47	0.46	0.59	<.01	0.01	1.5	<.01	1.9	1.3	0.64	5.6
Se	0.43	0.8	0.4	<.01	0.05	0.6	<.01	3.4	3.8	2	8.6
Si	16	17	2.4	<.01	1.8	<.01	<.01	5.1	4.6	8.2	16
Sn	0.44	0.13	0.09	<.01	<.01	<.01	<.01	0.54	0.6	4	1.4
Sr	0.2	0.2	0.18	0.7	1.1	2.2	0.2	1.1	1.1	0.96	0.74
Te	0.72	0.49	0.76	<.01	<.005	0.39	<.01	2	1.6	1.6	13
Th	0.64	0.48	0.45	<.01	0.08	0.5	0.1	1.9	0.9	0.45	5.1
Ti	0.03	0.03	0.03	<.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01
U	2	1.8	2.7	<.01	<.01	3.2	4	8.7	5.4	1.8	28
V	0.09	0.08	0.07	0.03	0.01	0.07	0.04	0.02	0.04	0.03	0.06
W	1.1	0.29	0.48	<.01	0.01	0.1	0.1	1.9	1.9	3.6	38
Y	0.04	0.02	0.01	0.01	0.005	0.01	0.02	0.01	0.02	0.02	0.22
Zn	37	3.5	21	5	0.48	14.6	43	68	54	135	889
Zr	0.09	0.07	0.08	0.03	0.01	0.31	0.05	0.04	0.05	0.03	0.16
SUM, mg/L	4187	2447	609	713	1132	2274	2897	5483	5682	3469	12518

PIEZOMETER	H8	H8	H8			
Setting	T	T	T			
Northing	15490	15490	15490			
Easting	11580	11580	11580			
Day/Mo/Yr	07-Nov-86	02-Apr-87	12-Apr-88	MAXIMA	MINIMA	Parameter
Temp C	5.5			10.0	3.5	Temp C
pH, Fld	5.05	4.51	4.52	7.1	0.0	pH, Fld
pH, lab				7.1	2.8	pH, lab
Cond.,Fld	9000	9200		13500.0	110.0	Cond.,Fld
Cond.,lab				11000.0	160.0	Cond.,lab
Acidity	27660			33728.0	13.5	Acidity
Element						Element
Ag	<.005	<.005	0.06	0.1	0.00	Ag
Al	14.9	26	61	61.0	0.12	Al xxx
As	3.7	43	0.2	43.0	0.00	As
B	6	0.6	23	23.0	0.00	B
Ba	<.005	0.05	0.1	0.1	0.00	Ba
Be	0.17	0.4	0.09	0.4	0.00	Be
Bi	2.3	5	0.8	5.0	0.00	Bi
C	165	194	107	3937.0	51.00	C xxx
Ca	349	379	403	864.0	28.00	Ca xxx
Cd	0.3	0.6	1	1.0	0.00	Cd
Ce	1.8	2	0.7	2.6	0.00	Ce
Co	1.9	2.9	8	8.0	0.00	Co
Cr	0.34	0.35	1	1.0	0.00	Cr
Cu	0.03	0.2	5	5.0	0.00	Cu
Fe	6490	3337	22990	22990.0	0.36	Fe xxx
Hg	1.5	3.2	0.2	3.2	0.00	Hg
K	20	19	11	81.0	6.00	K xxx
La	0.9	0.9	0.3	1.4	0.00	La
Mg	260	318	799	799.0	3.40	Mg xxx
Mn	75	90	228	228.0	0.42	Mn xxx
Mo	1.7	3	3	3.0	0.00	Mo
Na	15	10.1	10	80.0	3.00	Na xxx
Nb	0.91	1.8	0.3	2.0	0.00	Nb
Ni	1	1.9	3.6	3.6	0.02	Ni xxx
P	11	22	24	24.0	0.00	P
Pb	4.1	5	0.5	5.0	0.00	Pb
S	4221	5031	10198	10198.0	12.00	S xxx
Sb	4.5	34	1.9	34.0	0.00	Sb
Se	9	13	1.3	13.0	0.00	Se
Si	12	348	17	348.0	0.00	Si
Sn	1.8	3	0.1	44.0	0.00	Sn
Sr	0.9	0.9	1	4.0	0.05	Sr xxx
Te	11	16	2.2	16.0	0.00	Te
Th	3.3	6	16	16.0	0.00	Th
Ti	0.02	0.04	0.02	0.2	0.00	Ti
U	22	38	94	94.0	0.00	U
V	0.08	0.15	0.2	3.0	0.00	V
W	40	50	6.8	50.0	0.00	W
Y	0.3	0.36	1.1	1.1	0.00	Y
Zn	829	1123	789	1123.0	0.33	Zn xxx
Zr	0.17	1	0.6	1.0	0.00	Zr
SUM, ug/L	12582	11130	35810	35810	253	

GEOCHEMICAL CALCULATION RESULTS

PIEZOMETER #	M-4	M-4	M-5a	M-5a	M-5b	M-5b	M-7a	M-7a	M-7b	M-7b
Setting	B	B	B	B	B	B	T	T	B	B
Northing, ft	16380	16380	16020	16020	16020	16020	15810	15810	15810	15810
Easting, ft	11130	11130	11020	11020	11020	11020	12505	12505	12505	12505
Day/Mo/Yr	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88
SUM,mmole/L	146	177	96	355	307	472	500	305	463	261
T-freezing (C)	-0.27	-0.33	-0.18	-0.66	-0.57	-0.88	-0.93	-0.57	-0.86	-0.49
Sum CATIONS, meq/L	94.95	72.81	23.86	78.87	48.91	114.22	611.48	573.95	262.01	405.47
Sum ANIONS, meq/L	110.89	77.92	57.12	217.68	169.16	287.22	404.46	187.71	296.35	197.70
BALANCE ERROR%	-7.74%	-3.39%	-41.06%	-46.81%	-55.14%	-43.09%	20.38%	50.71%	-6.15%	34.45%
Fe	18.067	11.532	1.182	9.150	2.650	19.052	176.500	177.950	65.232	121.940
"Metal": Cu,Pb,Zn	0.922	0.691	0.936	2.479	0.875	2.022	9.644	5.319	1.401	5.289
S	38.459	38.958	10.200	39.114	18.434	50.405	176.794	93.855	76.700	92.608
Based on PYRRHOTITE:										
Fe/S	0.4698	0.2960	0.1159	0.2339	0.1438	0.3780	0.9983	1.8960	0.8505	1.3167
Fe/(S-Metal)	0.4813	0.3013	0.1276	0.2498	0.1509	0.3938	1.0559	2.0099	0.8663	1.3965
LOSS: (S-Metal)-Fe	19.47	26.74	8.08	27.49	14.91	29.33	-9.35	-89.41	10.07	-34.62
Based on PYRITE:										
Fe/0.5%S	0.9396	0.5920	0.2317	0.4679	0.2875	0.7560	1.9967	3.7920	1.7010	2.6335
Fe/(0.5%(S-Metal))	0.9626	0.6027	0.2551	0.4995	0.3019	0.7875	2.1119	4.0198	1.7326	2.7930
LOSS: 0.5%(S-Metal)-Fe	0.24	7.26	2.98	7.93	5.69	4.13	-97.75	-136.34	-28.28	-80.93
Sat.Degree - Calcite	-0.87		-0.22	-0.16	0.89	0.14	-1.50		0.08	-2.68
Sat.Degree - Dolomite	-2.09		-1.00	-0.72	1.30	-0.08	-2.70		0.12	-5.20
Sat.Degree - Gypsum	0.25	0.22	-0.30	0.27	0.04	0.35	0.22	-0.19	0.32	-0.13
Balance Error %	-18.28	-12.43	-43.34	-51.52	-57.13	-50.25	3.31	35.43	-20.3	17.56

GEOCHEMICAL CALCULATION RESULTS

PIEZOMETER #	M-9	M-9	M-24A	M-24A	M-24B	M-24B	M-25	M-26	M-26	M-27A
Setting	B	B	B	B	B	B	B	B	B	T
Northing, ft	15250	15250	15300	15300	15300	15300	16000	15940	15940	15750
Easting, ft	11885	11885	11080	11080	11080	11080	12485	12120	12120	11085
Day/Mo/Yr	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	06/11/86	12/04/88	06/11/86
SUM,meole/L	270	195	253	138	180	166	241	425	360	119
T-freezing (C)	-0.50	-0.36	-0.47	-0.26	-0.33	-0.31	-0.45	-0.79	-0.67	-0.22
Sum CATIONS, meq/L	230.70	150.75	284.66	284.14	96.00	119.02	8.07	9.97	14.24	6.05
Sum ANIONS, meq/L	194.75	142.75	203.46	53.90	129.41	109.11	119.64	210.62	180.60	59.44
BALANCE ERROR%	8.45%	2.72%	16.64%	68.11%	-14.82%	4.35%	-87.36%	-90.96%	-85.39%	-81.52%
Fe	61.525	38.391	79.378	87.364	22.007	27.933	0.018	0.197	0.501	0.008
"Metal": Cu,Pb,Zn	4.185	1.274	4.751	3.551	2.620	2.237	0.013	0.010	0.039	0.008
S	68.528	49.563	86.120	26.949	39.021	54.554	0.998	0.905	3.088	1.372
Based on PYRRHOTITE:										
Fe/S	0.8978	0.7746	0.9217	3.2418	0.5640	0.5120	0.0179	0.2178	0.1624	0.0057
Fe/(S-Metal)	0.9562	0.7950	0.9755	3.7338	0.6046	0.5339	0.0182	0.2202	0.1645	0.0058
LOSS: (S-Metal)-Fe	2.82	9.90	1.99	-63.97	14.39	24.38	0.97	0.70	2.55	1.36
Based on PYRITE:										
Fe/0.5%S	1.7956	1.5492	1.8434	6.4835	1.1279	1.0241	0.0359	0.4355	0.3247	0.0115
Fe/(0.5%(S-Metal))	1.9124	1.5900	1.9510	7.4676	1.2091	1.0679	0.0364	0.4404	0.3289	0.0115
LOSS: 0.5%(S-Metal)-Fe	-31.45	-14.88	-41.07	-77.44	-5.12	-2.89	0.47	0.25	1.00	0.67
Sat.Degree - Calcite	-0.85	-1.20	-2.06		-1.06		0.26	0.51	0.06	0.18
Sat.Degree - Dolomite	-1.92	-2.64	-4.09		-2.48		-0.10	0.17	-0.56	-0.82
Sat.Degree - Gypsum	0.22	0.14	0.12	-0.58	0.04	0.28	-1.74	-1.79	-1.15	-1.63
Balance Error %	-7.29	-12.07	0.11	56.92	-27.41	-10.23	-87.44	-91.17	-85.94	-81.66

GEOCHEMICAL CALCULATION RESULTS

PIEZOMETER #	M-27A	M-27B	M-27B	M-30	M-30	M-31	M-31	M-32	M-32	M-40
Setting	T	T	T	B	B	B	B	B	B	B
Northing, ft	15750	15750	15750	16435	16435	16900	16900	15500	15500	15890
Easting, ft	11085	11085	11085	11700	11700	13080	13080	12150	12150	11730
Day/Mo/Yr	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86
SUM,meole/L	156	75	87	49	23	28	44	328	226	224
T-freezing (C)	-0.29	-0.14	-0.16	-0.09	-0.042	-0.052	-0.08	-0.61	-0.42	-0.42
Sum CATIONS, meq/L	13.76	14.16	27.44	2.40	3.95	1.23	0.94	103.87	80.70	58.48
Sum ANIONS, meq/L	83.68	41.68	60.70	24.31	12.90	13.64	21.56	208.04	144.66	134.70
BALANCE ERROR%	-71.76%	-49.27%	-37.74%	-82.04%	-53.16%	-83.47%	-91.65%	-33.40%	-28.38%	-39.46%
Fe	0.215	0.286	0.047	0.006	0.376	0.003		20.395	16.599	2.632
"Metal": Cu,Pb,Zn	0.030	0.062	0.062	0.007	0.041	0.002	0.001	4.364	0.860	0.187
S	6.581	5.646	16.906	0.374	1.747	0.115	0.125	43.699	32.283	25.016
Based on PYRRHOTITE:										
Fe/S	0.0326	0.0507	0.0028	0.0172	0.2153	0.0233		0.4667	0.5142	0.1052
Fe/(S-Metal)	0.0328	0.0513	0.0028	0.0175	0.2205	0.0237		0.5185	0.5282	0.1060
LOSS: (S-Metal)-Fe	6.34	5.30	16.80	0.36	1.33	0.11	0.12	18.94	14.82	22.20
Based on PYRITE:										
Fe/0.5%S	0.0653	0.1015	0.0055	0.0344	0.4306	0.0465		0.9334	1.0283	0.2104
Fe/(0.5%(S-Metal))	0.0656	0.1026	0.0055	0.0351	0.4410	0.0474	0.0000	1.0370	1.0565	0.2120
LOSS: 0.5%(S-Metal)-Fe	3.05	2.47	8.34	0.17	0.46	0.05	0.06	-2.91	-1.32	9.69
Sat.Degree - Calcite	0.03	-0.14	-0.90	-0.93	-1.19	-1.29	-0.98	-0.43	-0.54	0.43
Sat.Degree - Dolomite	-0.75	-1.27	-2.35	-2.69	-3.08	-3.28	-2.61	-1.21	-1.46	0.26
Sat.Degree - Gypsum	-0.70	-0.57	0.00	-2.38	-1.57	-3.21	-3.27	0.14	0.05	0.30
Balance Error %	-72.23	-50.2	-37.9	-82.46	-57.01	-84.21	-91.85	-42.91	-38.73	-41.49

GEOCHEMICAL CALCULATION RESULTS

PIEZOMETER #	M-40	M-41	M-41	M-43	M-43	M-46	M-46	H1	H1	H2
Setting	B	B	B	B	B	B	B	T	T	T
Northing, ft	15890	16075	16075	15690	15690	15370	15370	15300	15300	15220
Easting, ft	11730	11410	11410	12360	12360	12020	12020	11705	11705	11360
Day/Mo/Yr	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	06/11/86	12/04/88	15/10/86	06/11/86	15/10/86
SUM,meole/L	94	388	547	331	172	252	261	50	67	122
T-freezing (C)	-0.17	-0.72	-1.02	-0.62	-0.32	-0.47	-0.48	-0.09	-0.12	-0.23
Sum CATIONS, meq/L	79.21	9.11	17.84	275.09	291.10	110.12	139.80	47.92	45.56	124.38
Sum ANIONS, meq/L	82.41	192.16	274.72	236.29	126.64	170.38	195.20	43.15	51.52	99.58
BALANCE ERROR%	-1.98%	-90.94%	-87.80%	7.59%	39.37%	-21.49%	-16.54%	5.24%	-6.14%	11.07%
Fe	9.813	0.251	0.304	74.758	85.698	21.129	23.350	4.781	5.533	31.694
"Metal": Cu,Pb,Zn	0.706	0.015	0.046	4.781	3.463	2.865	9.211	0.719	0.033	1.028
S	41.204	0.624	4.273	81.098	63.319	44.729	63.256	19.370	18.933	41.672
Based on PYRRHOTITE:										
Fe/S	0.2381	0.4018	0.0712	0.9218	1.3534	0.4724	0.3691	0.2468	0.2922	0.7606
Fe/(S-Metal)	0.2423	0.4120	0.0720	0.9796	1.4317	0.5047	0.4320	0.2563	0.2927	0.7798
LOSS: (S-Metal)-Fe	30.69	0.36	3.92	1.56	-25.84	20.73	30.70	13.87	13.37	8.95
Based on PYRITE:										
Fe/0.5%S	0.4763	0.8037	0.1425	1.8436	2.7069	0.9448	0.7382	0.4936	0.5845	1.5211
Fe/(0.5%(S-Metal))	0.4846	0.8239	0.1440	1.9591	2.8635	1.0094	0.8641	0.5127	0.5855	1.5596
LOSS: 0.5%(S-Metal)-Fe	10.08	0.05	1.79	-38.99	-57.50	-1.63	-0.93	4.18	3.90	-11.89
Sat.Degree - Calcite		-0.03	-0.03	-0.85		-0.25	-0.67	-1.28	-0.24	-0.96
Sat.Degree - Dolomite		-0.91	-0.70	-1.80		-0.83	-1.82	-3.54	-1.40	-2.55
Sat.Degree - Gypsum	0.38	-2.01	-1.00	0.20	-0.06	0.25	0.47	0.24	0.17	0.19
Balance Error %	-10.7	-91.31	-88.01	-8.4	23.35	-31.47	-25.33	-0.06	-12.6	-3.73

GEOCHEMICAL CALCULATION RESULTS

PIEZOMETER #	H2	H3	H4	H4	H5	H5	H5	H6	H6	H7
Setting	T	T	T	T	T	T	T	T	T	T
Northing, ft	15220	15310	15400	15400	15445	15445	15445	15505	15505	15645
Easting, ft	11360	11225	11485	11485	11730	11730	11730	11955	11955	12020
Day/Mo/Yr	08/11/86	08/11/86	08/11/86	12/04/88	06/11/86	02/04/87	12/04/88	15/10/86	06/11/86	07/11/86
SUM,meole/L	129	91	29	36	51	99	92	144	164	156
T-freezing (C)	-0.24	-0.17	-0.05	-0.07	-0.09	-0.18	-0.17	-0.27	-0.30	-0.29
Sum CATIONS, meq/L	133.34	72.80	15.81	14.33	29.68	59.31	67.78	191.34	195.25	88.82
Sum ANIONS, meq/L	106.88	69.07	18.14	27.52	36.75	73.09	93.39	121.70	132.43	118.79
BALANCE ERROR%	11.02%	2.63%	-6.86%	-31.53%	-10.66%	-10.41%	-15.89%	22.25%	19.17%	-14.44%
Fe	33.950	14.719	0.555	0.143	1.056	2.453	3.832	48.722	50.996	17.011
"Metal": Cu,Pb,Zn	0.570	0.056	0.325	0.082	0.008	0.223	0.661	1.045	0.832	2.068
S	45.321	25.920	5.490	9.389	13.007	25.764	46.694	57.392	58.141	39.582
Based on PYRRHOTITE:										
Fe/S	0.7491	0.5679	0.1011	0.0153	0.0812	0.0952	0.0821	0.8489	0.8771	0.4298
Fe/(S-Metal)	0.7586	0.5691	0.1075	0.0154	0.0813	0.0960	0.0832	0.8647	0.8899	0.4535
LOSS: (S-Metal)-Fe	10.80	11.15	4.61	9.16	11.94	23.09	42.20	7.62	6.31	20.50
Based on PYRITE:										
Fe/0.5%S	1.4982	1.1357	0.2022	0.0305	0.1624	0.1904	0.1641	1.6979	1.7542	0.8595
Fe/(0.5%(S-Metal))	1.5173	1.1382	0.2150	0.0308	0.1626	0.1921	0.1665	1.7294	1.7797	0.9069
LOSS: 0.5%(S-Metal)-Fe	-11.86	-1.81	1.86	4.47	5.44	10.21	18.85	-21.07	-22.76	0.71
Sat.Degree - Calcite	-0.99	-0.83	-1.14	-0.72	-0.42	-0.38		-1.54	-1.43	-0.47
Sat.Degree - Dolomite	-2.67	-2.56	-3.05	-2.19	-1.59	-1.87		-3.16	-2.78	-1.35
Sat.Degree - Gypsum	0.26	0.19	-0.58	-0.45	-0.01	0.47	0.53	0.21	0.20	0.23
Balance Error %	-3.82	-8.79	-9.2	-32.74	-12.51	-12.75	-18.85	7.8	4.16	-24.81

GEOCHEMICAL CALCULATION RESULTS

PIEZOMETER #	HB	HB	HB	HB	MAXIMA	MINIMA	
Setting	T	T	T	T			
Northing, ft	15490	15490	15490	15490			
Easting, ft	11580	11580	11580	11580			
Day/Mo/Yr	15/10/86	07/11/86	02/04/87	12/04/88	mg/L	mg/L	PARAMETER
SUM,mmole/L	289	313	291	805	805.2	22.8	SUM,mmole/L
T-freezing (C)	-0.54	-0.58	-0.54	-1.50	-0.042	-1.50	T-freezing (C)
Sum CATIONS, meq/L	436.19	418.44	265.91	1361.05	1361.0	0.9	CATIONS
Sum ANIONS, meq/L	246.17	277.06	313.85	636.18	636.2	12.9	ANIONS
BALANCE ERROR%	27.85%	20.33%	-8.27%	36.29%	0.7	-0.9	ERROR%
Fe	123.068	116.210	59.753	411.660	411.7	0.003	Fe
"Metal": Cu,Pb,Zn	13.613	12.700	17.204	12.149	17.2	0.001	Metals: Cu,Pb,Zn
S	120.961	131.659	156.925	318.091	318.1	0.115	S
Based on PYRRHOTITE:							
Fe/S	1.0174	0.8827	0.3808	1.2942	3.2	0.003	Fe/S
Fe/(S-Metal)	1.1464	0.9769	0.4277	1.3456	3.7	0.003	Fe/(S-Metals)
LOSS: (S-Metal)-Fe	-15.72	2.75	79.97	-105.72	80.0	-105.718	LOSS(S-Metals)-Fe
Based on PYRITE:							
Fe/0.5%S	2.0348	1.7653	0.7615	2.5883	6.5	0.006	Fe/0.5%S
Fe/(0.5%(S-Metal))	2.2929	1.9538	0.8553	2.6911	7.5	0.000	Fe/(0.5%S-Metals)
LOSS: 0.5%(S-Metal)-Fe	-76.20	-63.08	1.51	-264.76	18.9	-264.764	LOSS(0.5%S-Metals
Sat.Degree - Calcite	-3.07	-2.50			0.9	-3.070	Sat. - Calcite
Sat.Degree - Dolomite	-6.13	-5.03			1.3	-6.130	Sat. - Dolomite
Sat.Degree - Gypsum	0.18	0.27	0.42	0.35	0.5	-3.270	Sat. - Gypsum
Balance Error %	11.59	3.87	-21.73	19.22	56.9	-91.850	Balance Error %

RATE CALCULATIONS

LOCATION and setting		UNSATURATED THICKNESS, m		[S], mg/L		[S], millimole/L	
		MAX.	MIN.	MAX.	MIN.	MAX.	MIN.
4	B	2.80	2.65	1249	1233	38.96	38.46
5A	B	1.28	1.28	1254	327	39.11	10.20
5B	B	1.28	1.28	1616	591	50.41	18.43
7A	T	2.73	1.72	6735	3009	210.07	93.86
7B	B	3.02	2.09	5193	2459	161.98	76.70
9	B	3.40	2.58	2197	1589	68.53	49.56
24A	B	1.73	1.73	2761	864	86.12	26.95
24B	B	1.73	1.73	1749	1251	54.55	39.02
25	B	0.72	0.00	32	32	1.00	1.00
26	B	0.67	0.23	99	29	3.09	0.90
27A	T	2.30	0.90	211	44	6.58	1.37
27B	T	2.16	0.62	542	181	16.91	5.65
30	B	0.97	0.00	56	12	1.75	0.37
32	B	2.34	2.34	1401	1035	43.70	32.28
40	B	2.50	1.40	1321	802	41.20	25.02
41	B	1.21	0.00	137	20	4.27	0.62
43	B	2.73	1.55	2600	2030	81.10	63.32
46	B	3.53	2.68	2028	1434	63.26	44.73
H1	T	1.58	0.16	621	607	19.37	18.93
H2	T	2.34	1.17	1453	1336	45.32	41.67
H3	T	2.37	0.68	831	831	25.92	25.92
H4	T	1.39	0.00	301	176	9.39	5.49
H5	T	1.15	0.00	1497	417	46.69	13.01
H6	T	1.96	0.71	1864	1840	58.14	57.39
H7	T	2.08	0.75	1269	1269	39.58	39.58
H8	T	1.61	0.10	10198	3878	318.09	120.96
Averages		1.98	1.09	1893	1050	59.0	32.7
Overall AVE.			1.54		1471		45.9
		Unsaturated, m		[S], mg/L		[S], millimole/L	

H1-H3 go DRY; M27, H1-H8 have TD in tailings

SULFIDE OXIDATION RATES

AREA, m^2		200,000
RECHARGE, m	0.175 MIN., and	0.275 MAX.
MINERAL DENSITY, kg/m^3		3650
POROSITY, fraction		0.3
BULK DENSITY, kg/m^3		2555

LOCATION and setting		[S], millimole/L (corrected, App.I-1)		S FLUX mole.m-2.yr-1		S production Rate mole.m-2.m-1.yr-1		SULFIDE OXIDATION mole.kg-1.yr-1	
		MAX.	MIN.	[S MAX]x (P MIN)	[S MIN]x (P MAX)	[S MAX]x (P MIN)/ UNSAT.MAX	[S MIN]x (P MAX)/ UNSAT.MIN	"MAX."	"MIN."
4	B	38.96	38.46	6.8	10.6	2.43	3.99	0.0010	0.0016
5A	B	39.11	10.20	6.8	2.8	5.35	2.19	0.0021	0.0009
5B	B	50.41	18.43	8.8	5.1	6.89	3.96	0.0027	0.0016
7A	T	210.07	183.27	36.8	50.4	13.46	29.27	0.0053	0.0115
7B	B	161.98	76.70	28.3	21.1	9.39	10.09	0.0037	0.0040
9	B	68.53	49.56	12.0	13.6	3.53	5.29	0.0014	0.0021
24A	B	86.12	90.92	15.1	25.0	8.69	14.42	0.0034	0.0056
24B	B	54.55	39.02	9.5	10.7	5.52	6.20	0.0022	0.0024
25	B	1.00	1.00	0.2	0.3	0.24		0.0001	
26	B	3.09	0.90	0.5	0.2	0.81	1.09	0.0003	0.0004
27A	T	6.58	1.37	1.2	0.4	0.50	0.42	0.0002	0.0002
27B	T	16.91	5.65	3.0	1.6	1.37	2.51	0.0005	0.0010
30	B	1.75	0.37	0.3	0.1	0.32		0.0001	
32	B	43.70	32.28	7.6	8.9	3.27	3.79	0.0013	0.0015
40	B	41.20	25.02	7.2	6.9	2.88	4.91	0.0011	0.0019
41	B	4.27	0.62	0.7	0.2	0.62		0.0002	
43	B	81.10	89.16	14.2	24.5	5.20	15.80	0.0020	0.0062
46	B	63.26	44.73	11.1	12.3	3.14	4.59	0.0012	0.0018
H1	T	19.37	18.93	3.4	5.2	2.15	32.57	0.0008	0.0127
H2	T	45.32	41.67	7.9	11.5	3.39	9.80	0.0013	0.0038
H3	T	25.92	25.92	4.5	7.1	1.91	10.48	0.0007	0.0041
H4	T	9.39	5.49	1.6	1.5	1.18		0.0005	
H5	T	46.69	13.01	8.2	3.6	7.11		0.0028	
H6	T	58.14	57.39	10.2	15.8	5.19	22.22	0.0020	0.0087
H7	T	39.58	39.58	6.9	10.9	3.33	14.51	0.0013	0.0057
H8	T	318.09	136.68	55.7	37.6	34.48	359.64	0.0135	0.1408
Averages		59.0	40.2	10.3	11.1	5.1	26.6	0.0020	0.0104
Overall AVE			49.6		10.7		14.7		0.0057
		[S]corr., millimole/L		S FLUX mole.m-2.yr-1		S production Rate mole.m-2.m-1.yr-1		SULFIDE OXIDATION mole.kg-1.yr-1	

209,843 kg H2SO4/yr

IRON PRECIPITATION RATES

AREA, m^2		200,000
RECHARGE, m	0.175 MIN., and	0.275 MAX.
MINERAL DENSITY, kg/m^3		3650
POROSITY, fraction		0.3
BULK DENSITY, kg/m^3		2555

LOCATION and setting		Fe LOSS (based on PYRITE) millimole/L		Fe LOSS mole.m-2.yr-1		Fe precipitation Rate mole.m-2.m-1.yr-1		IRON PRECIPITATION mole.kg-1.yr-1	
		MAX.	MIN.	[Fe MAX]x (P MIN)	[Fe MIN]x (P MAX)	[Fe MAX]x (P MIN)/ UNSAT.MAX	[Fe MIN]x (P MAX)/ UNSAT.MIN	"MAX."	"MIN."
4	B	7.26	0.24	1.27	0.07	0.4538	0.0249	0.000178	0.000010
5A	B	7.93	2.98	1.39	0.82	1.0842	0.6402	0.000424	0.000251
5B	B	5.69	4.13	1.00	1.14	0.7779	0.8873	0.000304	0.000347
7A	T								
7B	B								
9	B								
24A	B								
24B	B								
25	B	0.47	0.47	0.08	0.13	0.1142		0.000045	
26	B	1.00	0.25	0.18	0.07	0.2616	0.3004	0.000102	0.000118
27A	T	3.05	0.67	0.53	0.18	0.2320	0.2045	0.000091	0.000080
27B	T	8.34	2.47	1.46	0.68	0.6759	1.0969	0.000265	0.000429
30	B	0.46	0.17	0.08	0.05	0.0831		0.000033	
32	B								
40	B	10.08	9.69	1.76	2.66	0.7054	1.9023	0.000276	0.000745
41	B	1.79	0.05	0.31	0.01	0.2589		0.000101	
43	B								
46	B								
H1	T	4.18	3.90	0.73	1.07	0.4630	6.7092	0.000181	0.002626
H2	T								
H3	T								
H4	T	4.47	1.86	0.78	0.51	0.5630		0.000220	
H5	T	18.85	5.44	3.30	1.50	2.8708		0.001124	
H6	T								
H7	T	0.71	0.71	0.12	0.20	0.0597	0.2603	0.000023	0.000102
H8	T	1.51	1.51	0.26	0.42	0.1637	3.9732	0.000064	0.001555
Averages		5.05	2.30	0.88	0.63	0.58	1.60	0.00023	0.00063
Overall AVE			3.68		0.76		0.99		0.00039
		Fe LOSS millimole/L		Fe LOSS mole.m-2.yr-1		Fe precipitation Rate mole.m-2.m-1.yr-1		IRON PRECIPITATION mole.kg-1.yr-1	

16,217 kg Fe(OH)3/yr

SOUTH BAY - BOREHOLE LOGS (in metres)

Piezom. No.		Fill	Tailings	Peat	Sand	Gravel	Bedrock	T.D.
4	B	0.15	3.05	0.03	4.39	0.00	2.13	9.75
5A	B	0.15	1.53	0.03	12.62	0.00	0.00	14.33
5B	B	0.15	1.53	0.03	3.63	0.00	0.00	5.34
7A	T	0.15	5.03	0.00	0.00	0.00	0.00	5.18
7B	B	0.15	5.03	0.00	5.00	0.00	1.52	11.70
9	B	0.15	4.42	0.00	0.00	1.22	1.83	7.62
24A	B	0.15	1.98	0.06	6.10	0.00	0.00	8.29
24B	B	0.15	1.98	0.06	3.91	0.00	0.00	6.10
25	B	0.15	1.98	0.03	3.02	0.00	0.00	5.18
26	B	0.15	2.90	0.03	2.56	0.00	0.00	5.64
27A	T	0.15	5.03	0.92	0.00	0.00	0.00	6.10
27B	T	0.15	4.42	0.00	0.00	0.00	0.00	4.57
30	B	0.15	2.29	0.03	1.95	0.00	0.00	4.42
32	B	0.15	2.59	0.00	6.10	1.83	0.00	10.67
40	B	0.15	4.12	0.00	1.52	0.00	2.13	7.92
41	B	0.15	3.51	0.30	1.22	0.00	0.00	5.18
43	B	0.15	4.42	0.00	4.88	0.00	1.52	10.97
46	B	0.15	4.42	0.00	5.18	0.00	1.52	11.28
H1	T	0.15	1.95	0.00	0.00	0.00	0.00	2.10
H2	T	0.15	2.70	0.00	0.00	0.00	0.00	2.85
H3	T	0.15	2.74	0.00	0.00	0.00	0.00	2.89
H4	T	0.15	2.08	0.00	0.00	0.00	0.00	2.23
H5	T	0.15	2.26	0.00	0.00	0.00	0.00	2.41
H6	T	0.15	2.36	0.00	0.00	0.00	0.00	2.51
H7	T	0.15	2.74	0.00	0.00	0.00	0.00	2.89
H8	T	0.15	2.11	0.00	0.00	0.00	0.00	2.26

Piezom. No.		WL DEPTH, m. MAX.	WL DEPTH, m. MIN.	WL DEPTH, m. RANGE	UNSATURATED, m MAX.	UNSATURATED, m MIN.	% UNSATURATED MAX.	% UNSATURATED MIN.
4	B	3.49	3.05	0.44	3.05	2.90	100%	95%
5A	B	3.74	3.19	0.55	1.53	1.53	100%	100%
5B	B	2.93	1.69	1.24	1.53	1.53	100%	100%
7A	T	3.13	2.12	1.01	2.98	1.97	59%	39%
7B	B	3.42	2.49	0.93	3.27	2.34	65%	47%
9	B	3.80	2.98	0.82	3.65	2.83	83%	64%
24A	B	3.95	3.25	0.70	1.98	1.98	100%	100%
24B	B	3.75	3.09	0.66	1.98	1.98	100%	100%
25	B	1.12	0.28	0.84	0.97	0.13	49%	7%
26	B	1.07	0.63	0.44	0.92	0.48	32%	17%
27A	T	2.70	1.30	1.40	2.55	1.15	51%	23%
27B	T	2.56	1.02	1.54	2.41	0.87	55%	20%
30	B	1.37	0.32	1.05	1.22	0.17	53%	7%
32	B	3.70	2.81	0.89	2.59	2.59	100%	100%
40	B	2.90	1.80	1.10	2.75	1.65	67%	40%
41	B	1.61	0.34	1.27	1.46	0.19	42%	5%
43	B	3.13	1.95	1.18	2.98	1.80	67%	41%
46	B	3.93	3.08	0.85	3.78	2.93	85%	66%
H1	T	1.98	0.56	1.42	1.83	0.41	94%	21%
H2	T	2.74	1.57	1.17	2.59	1.42	96%	53%
H3	T	2.77	1.08	1.69	2.62	0.93	96%	34%
H4	T	1.79	0.11	1.68	1.64	-0.04	79%	-2%
H5	T	1.55	0.14	1.41	1.40	-0.01	62%	-0%
H6	T	2.36	1.11	1.25	2.21	0.96	94%	41%
H7	T	2.48	1.15	1.33	2.33	1.00	85%	37%
H8	T	2.01	0.50	1.51	1.86	0.35	88%	17%

H1-H3 go DRY. M27 and H1-H8 have TD in TAILINGS

RATE CALCULATIONS

Based on 0.15 m inert cover on tailings

LOCATION and setting		UNSATURATED THICKNESS, m		[S], mg/L		[S], millimole/L	
		MAX.	MIN.	MAX.	MIN.	MAX.	MIN.
4	B	3.05	2.90	1249	1233	38.96	38.46
5A	B	1.53	1.53	1254	327	39.11	10.20
5B	B	1.53	1.53	1616	591	50.41	18.43
7A	T	2.98	1.97	6735	3009	210.07	93.86
7B	B	3.27	2.34	5193	2459	161.98	76.70
9	B	3.65	2.83	2197	1589	68.53	49.56
24A	B	1.98	1.98	2761	864	86.12	26.95
24B	B	1.98	1.98	1749	1251	54.5	
25	B	0.97	0.25	32	32	1.0	
26	B	0.92	0.48	99	29	3.0	
27A	T	2.55	1.15	211	44	6.5	
27B	T	2.41	0.87	542	181	16.9	
30	B	1.22	0.25	56	12	1.7	
32	B	2.59	2.59	1401	1035	43.7(	
40	B	2.75	1.65	1321	802	41.2(	
41	B	1.46	0.25	137	20	4.27	
43	B	2.98	1.80	2600	2030	81.10	
46	B	3.78	2.93	2028	1434	63.26	
H1	T	1.83	0.41	621	607	19.37	
H2	T	2.59	1.42	1453	1336	45.32	
H3	T	2.62	0.93	831	831	25.92	
H4	T	1.64	0.25	301	176	9.39	
H5	T	1.40	0.25	1497	417	46.69	
H6	T	2.21	0.96	1864	1840	58.14	
H7	T	2.33	1.00	1269	1269	39.58	
H8	T	1.86	0.35	10198	3878	318.09	120.96
Averages		2.23	1.34	1893	1050	59.0	32.7
Overall AVE.			1.79		1471		45.9
		Unsaturated, m		[S], mg/L		[S], millimole/L	

H1-H3 go DRY; M27, H1-H8 have TD in tailings

SULFIDE OXIDATION RATES

AREA, m^2		200,000
RECHARGE, m	0.175 MIN., and	0.275 MAX.
MINERAL DENSITY, kg/m^3		3650
POROSITY, fraction		0.3
BULK DENSITY, kg/m^3		2555

LOCATION and setting		[S], millimole/L (corrected, App.I-1)		S FLUX mole.m-2.yr-1		S production Rate mole.m-2.m-1.yr-1		SULFIDE OXIDATION mole.kg-1.yr-1	
		MAX.	MIN.	[S MAX]x (P MIN)	[S MIN]x (P MAX)	[S MAX]x (P MIN)/ UNSAT.MAX	[S MIN]x (P MAX)/ UNSAT.MIN	"MAX."	"MIN."
4	B	38.96	38.46	6.8	10.6	2.24	3.65	0.0009	0.0014
5A	B	39.11	10.20	6.8	2.8	4.47	1.83	0.0018	0.0007
5B	B	50.41	18.43	8.8	5.1	5.77	3.31	0.0023	0.0013
7A	T	210.07	183.27	36.8	50.4	12.33	25.56	0.0048	0.0100
7B	B	161.98	76.70	28.3	21.1	8.67	9.02	0.0034	0.0035
9	B	68.53	49.56	12.0	13.6	3.29	4.82	0.0013	0.0019
24A	B	86.12	90.92	15.1	25.0	7.60	12.60	0.0030	0.0049
24B	B	54.55	39.02	9.5	10.7	4.82	5.42	0.0019	0.0021
25	B	1.00	1.00	0.2	0.3	0.18		0.0001	
26	B	3.09	0.90	0.5	0.2	0.59	0.52	0.0002	0.0002
27A	T	6.58	1.37	1.2	0.4	0.45	0.33	0.0002	0.0001
27B	T	16.91	5.65	3.0	1.6	1.23	1.79	0.0005	0.0007
30	B	1.75	0.37	0.3	0.1	0.25		0.0001	
32	B	43.70	32.28	7.6	8.9	2.95	3.43	0.0012	0.0013
40	B	41.20	25.02	7.2	6.9	2.62	4.17	0.0010	0.0016
41	B	4.27	0.62	0.7	0.2	0.51		0.0002	
43	B	81.10	89.16	14.2	24.5	4.76	13.61	0.0019	0.0053
46	B	63.26	44.73	11.1	12.3	2.93	4.20	0.0011	0.0016
H1	T	19.37	18.93	3.4	5.2	1.85	12.70	0.0007	0.0050
H2	T	45.32	41.67	7.9	11.5	3.06	8.07	0.0012	0.0032
H3	T	25.92	25.92	4.5	7.1	1.73	7.66	0.0007	0.0030
H4	T	9.39	5.49	1.6	1.5	1.00		0.0004	
H5	T	46.69	13.01	8.2	3.6	5.84		0.0023	
H6	T	58.14	57.39	10.2	15.8	4.60	16.43	0.0018	0.0064
H7	T	39.58	39.58	6.9	10.9	2.97	10.88	0.0012	0.0043
H8	T	318.09	136.68	55.7	37.6	29.86	106.03	0.0117	0.0415
Averages		59.0	40.2	10.3	11.1	4.5	12.2	0.0018	0.0048
Overall AVE			49.6		10.7		7.9		0.0031
		[S]corr., millimole/L		S FLUX mole.m-2.yr-1		S production Rate mole.m-2.m-1.yr-1		SULFIDE OXIDATION mole.kg-1.yr-1	

209,843 kg H2SO4/yr

IRON PRECIPITATION RATES

AREA, m^2		200,000
RECHARGE, m	0.175 MIN., and	0.275 MAX.
MINERAL DENSITY, kg/m^3		3650
POROSITY, fraction		0.3
BULK DENSITY, kg/m^3		2555

LOCATION and setting		Fe LOSS (based on PYRITE) millimole/L		Fe LOSS mole.m-2.yr-1		Fe precipitation Rate mole.m-2.m-1.yr-1		IRON PRECIPITATION mole.kg-1.yr-1	
		MAX.	MIN.	[Fe MAX]* (P MIN)	[Fe MIN]* (P MAX)	[Fe MAX]* (P MIN)/ UNSAT.MAX	[Fe MIN]* (P MAX)/ UNSAT.MIN	"MAX."	"MIN."
4	B	7.26	0.24	1.27	0.07	0.4166	0.0228	0.000163	0.000009
5A	B	7.93	2.98	1.39	0.82	0.9070	0.5356	0.000355	0.000210
5B	B	5.69	4.13	1.00	1.14	0.6508	0.7423	0.000255	0.000291
7A	T								
7B	B								
9	B								
24A	B								
24B	B								
25	B	0.47	0.47	0.08	0.13	0.0847		0.000033	
26	B	1.00	0.25	0.18	0.07	0.1904	0.1436	0.000075	0.000056
27A	T	3.05	0.67	0.53	0.18	0.2093	0.1601	0.000082	0.000063
27B	T	8.34	2.47	1.46	0.68	0.6058	0.7814	0.000237	0.000306
30	B	0.46	0.17	0.08	0.05	0.0660		0.000026	
32	B								
40	B	10.08	9.69	1.76	2.66	0.6413	1.6142	0.000251	0.000632
41	B	1.79	0.05	0.31	0.01	0.2146		0.000084	
43	B								
46	B								
H1	T	4.18	3.90	0.73	1.07	0.3997	2.6168	0.000156	0.001024
H2	T								
H3	T								
H4	T	4.47	1.86	0.78	0.51	0.4771		0.000187	
H5	T	18.85	5.44	3.30	1.50	2.3578		0.000923	
H6	T								
H7	T	0.71	0.71	0.12	0.20	0.0533	0.1952	0.000021	0.000076
H8	T	1.51	1.51	0.26	0.42	0.1417	1.1713	0.000055	0.000458
Averages		5.05	2.30	0.88	0.63	0.49	0.80	0.00019	0.00031
Overall AVE			3.68		0.76		0.62		0.00024
		Fe LOSS millimole/L		Fe LOSS mole.m-2.yr-1		Fe precipitation Rate mole.m-2.m-1.yr-1		IRON PRECIPITATION mole.kg-1.yr-1	

16,217 kg Fe(OH)3/yr

Figure 1A

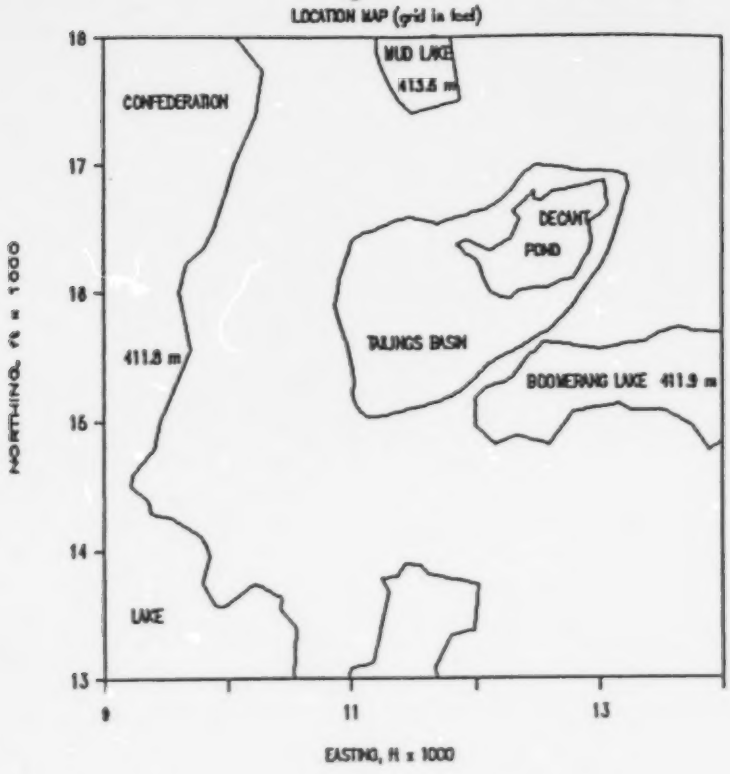

Figure 1B

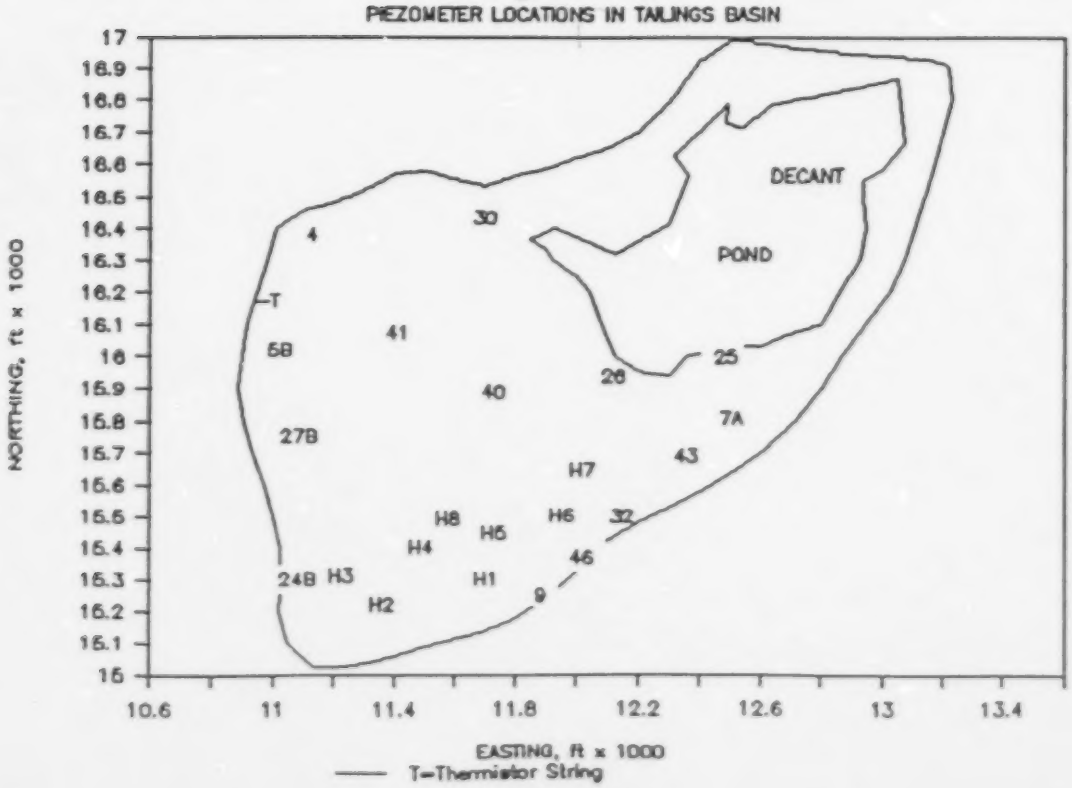

FIGURE 2A. 1971 TOPOGRAPHY (FT. + 1300)

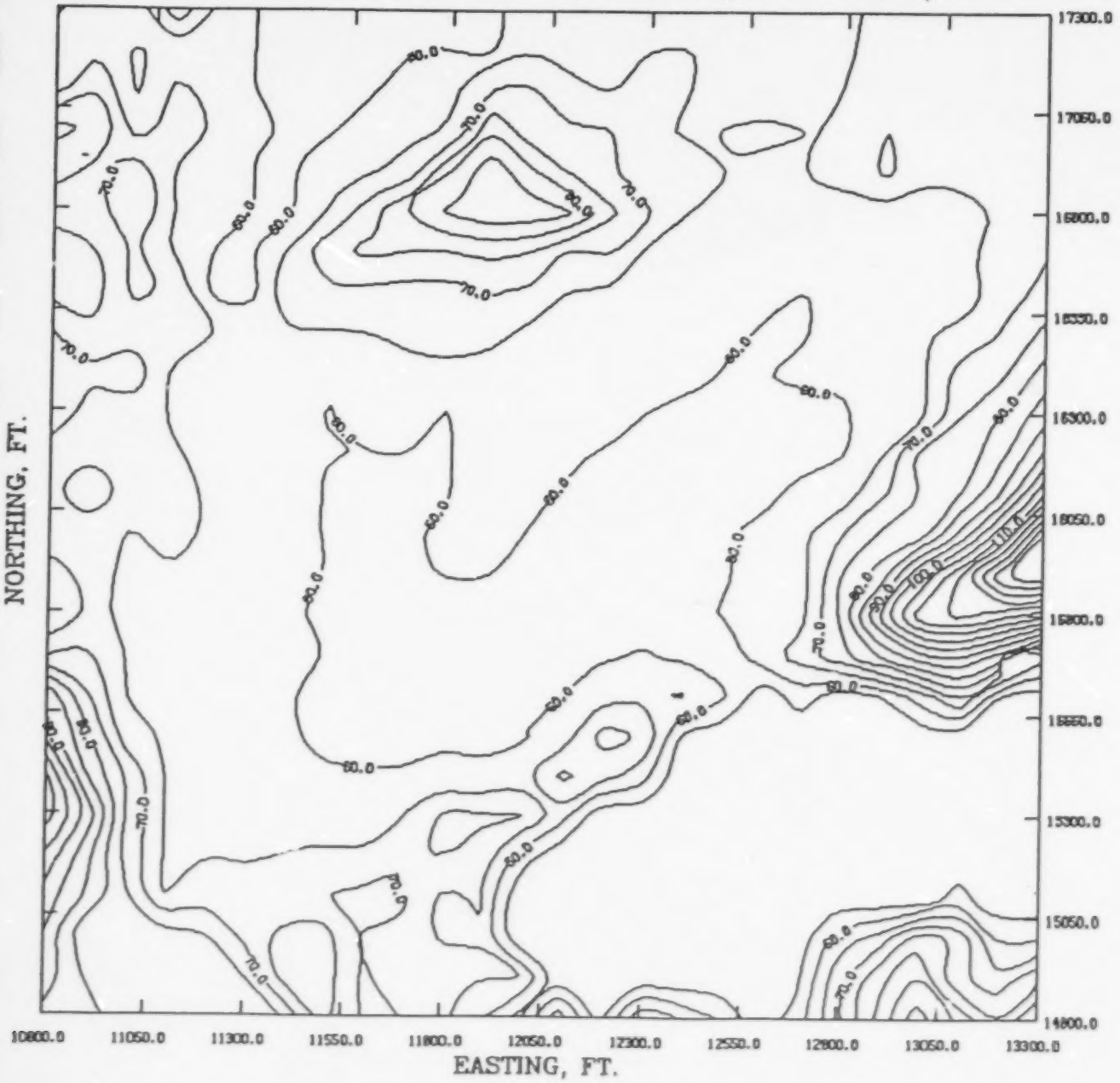

FIGURE 2B. 1987 TOPOGRAPHY (FT. + 1300)

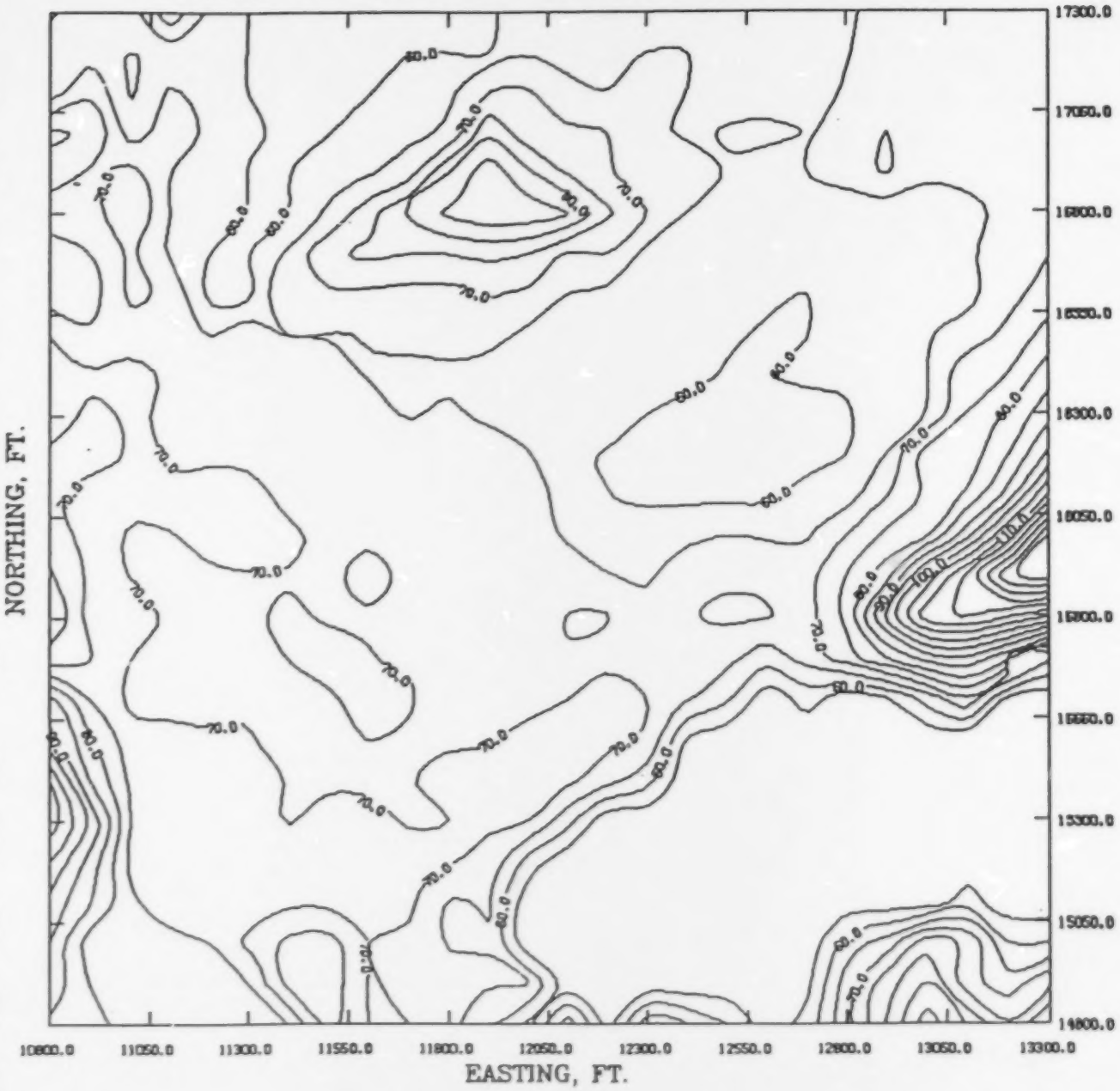

FIGURE 3A. TAILINGS ISOPACHS (M)

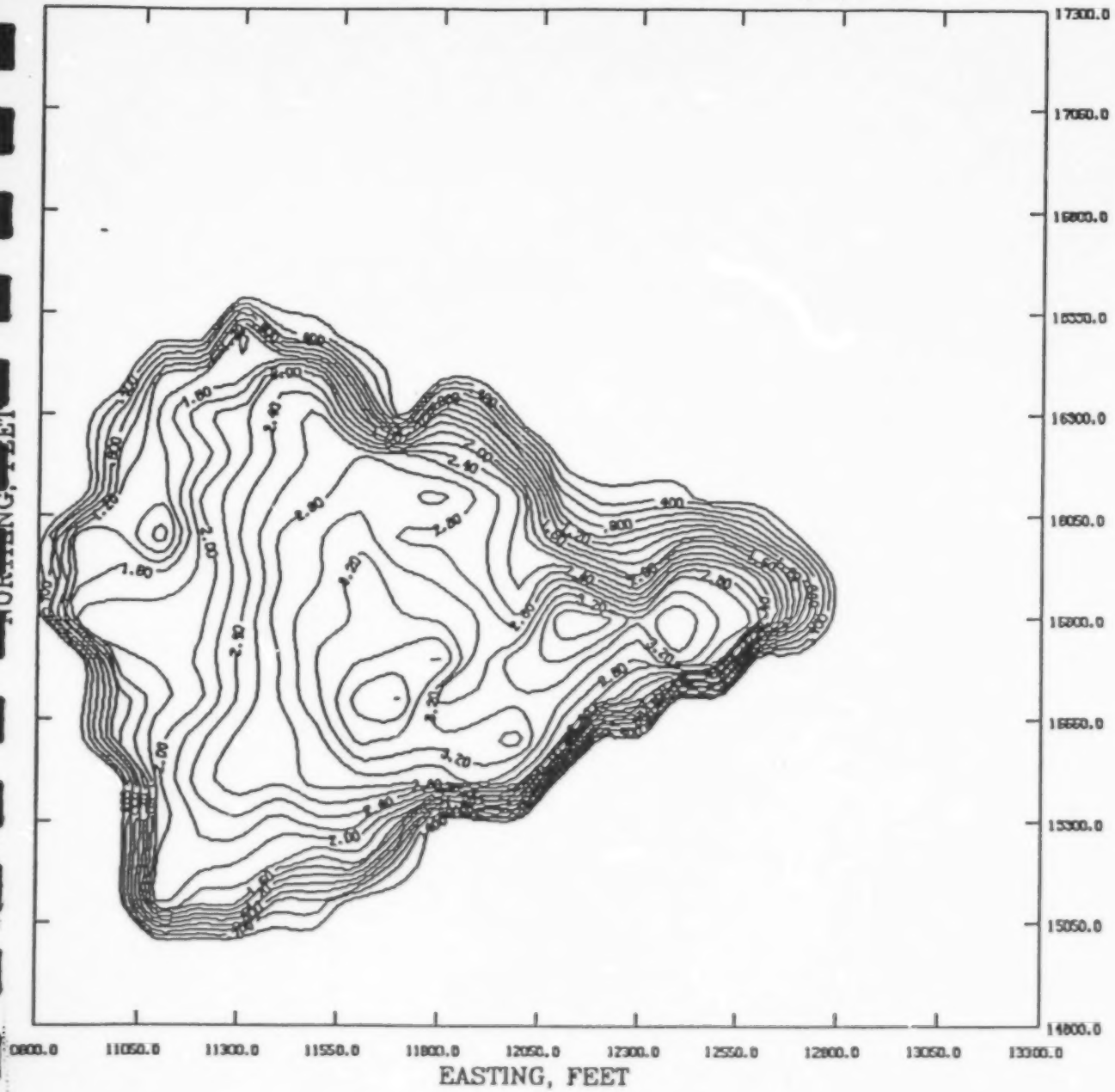

Figure 3B

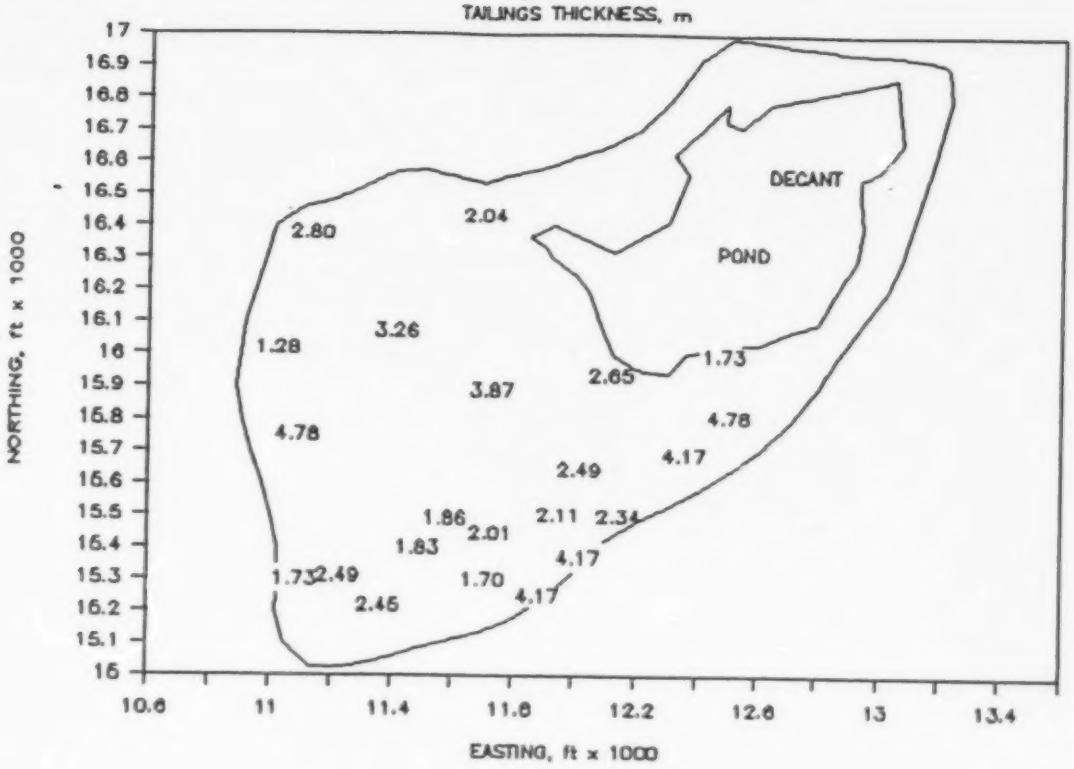
TAILINGS THICKNESS, m
NORTHING, ft x 1000
EASTING, ft x 1000
DECANT
POND
2.80
2.04
3.26
1.28
1.73
2.65
3.87
4.78
4.78
4.17
2.49
1.86
2.11
2.34
2.01
1.83
4.17
1.73
2.49
1.70
4.17
2.45
17
16.9
16.8
16.7
16.6
16.5
16.4
16.3
16.2
16.1
16
15.9
15.8
15.7
15.6
15.5
15.4
15.3
16.2
15.1
15
10.6
11
11.4
11.8
12.2
12.6
13
13.4

Figure 4A

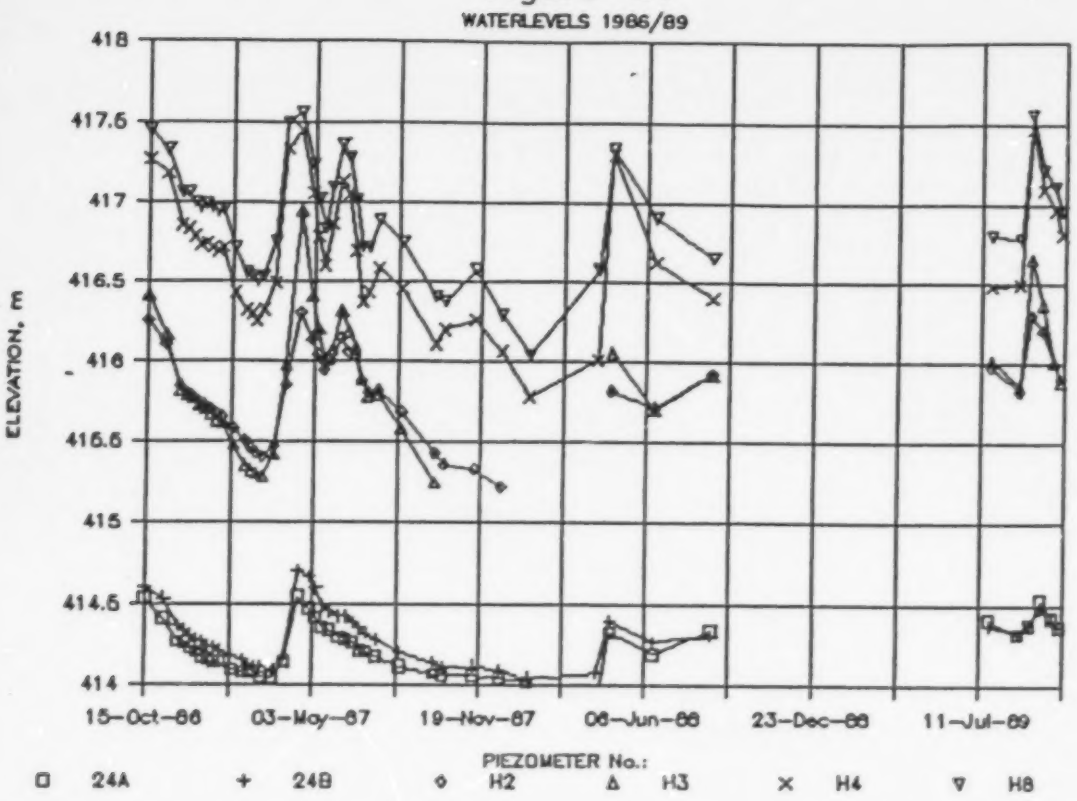

Figure 4B

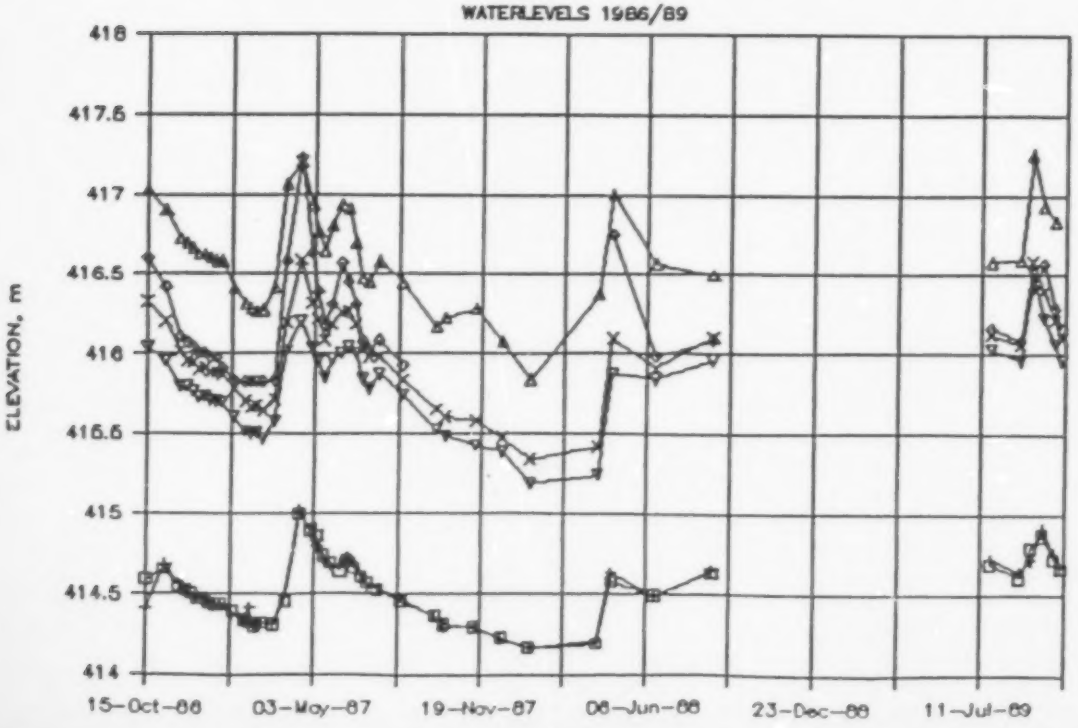

Figure 4C

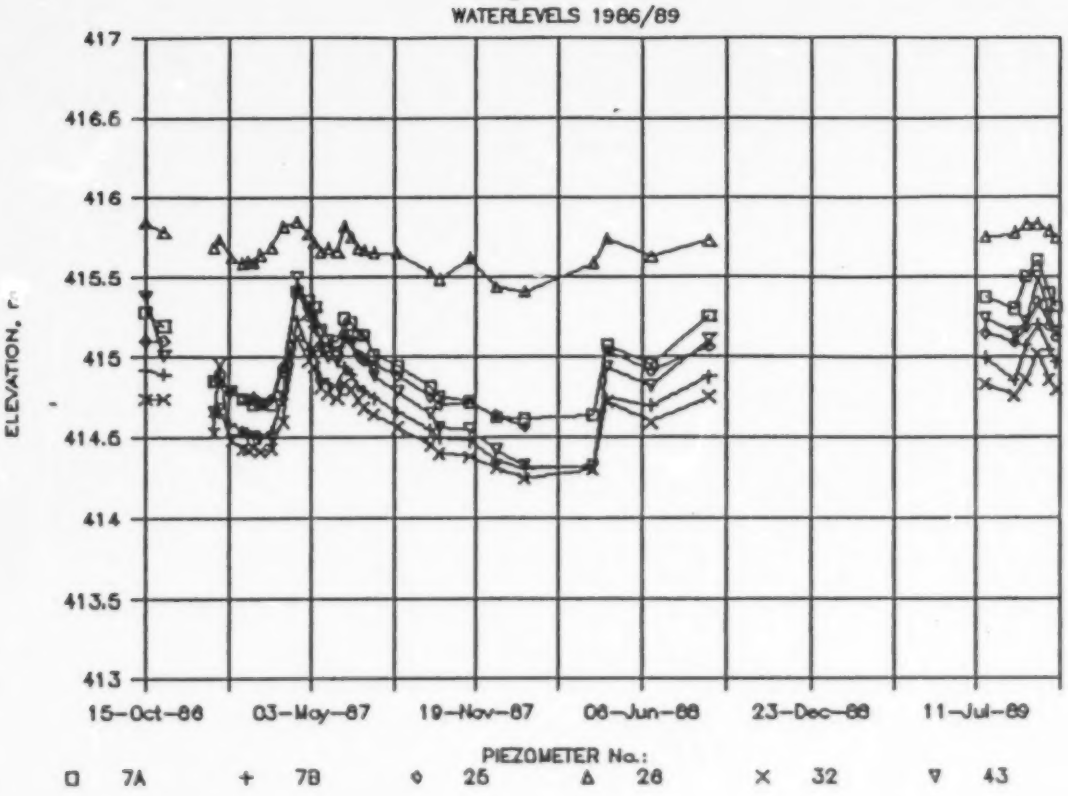

Figure 4D

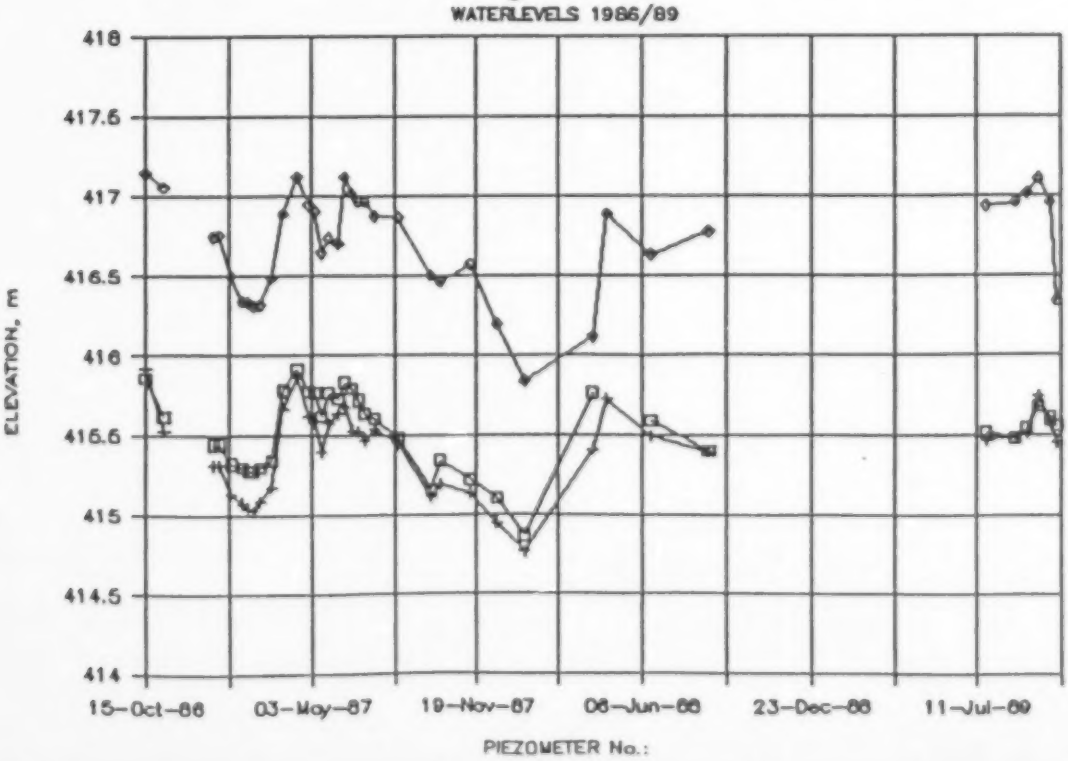

Figure 4E

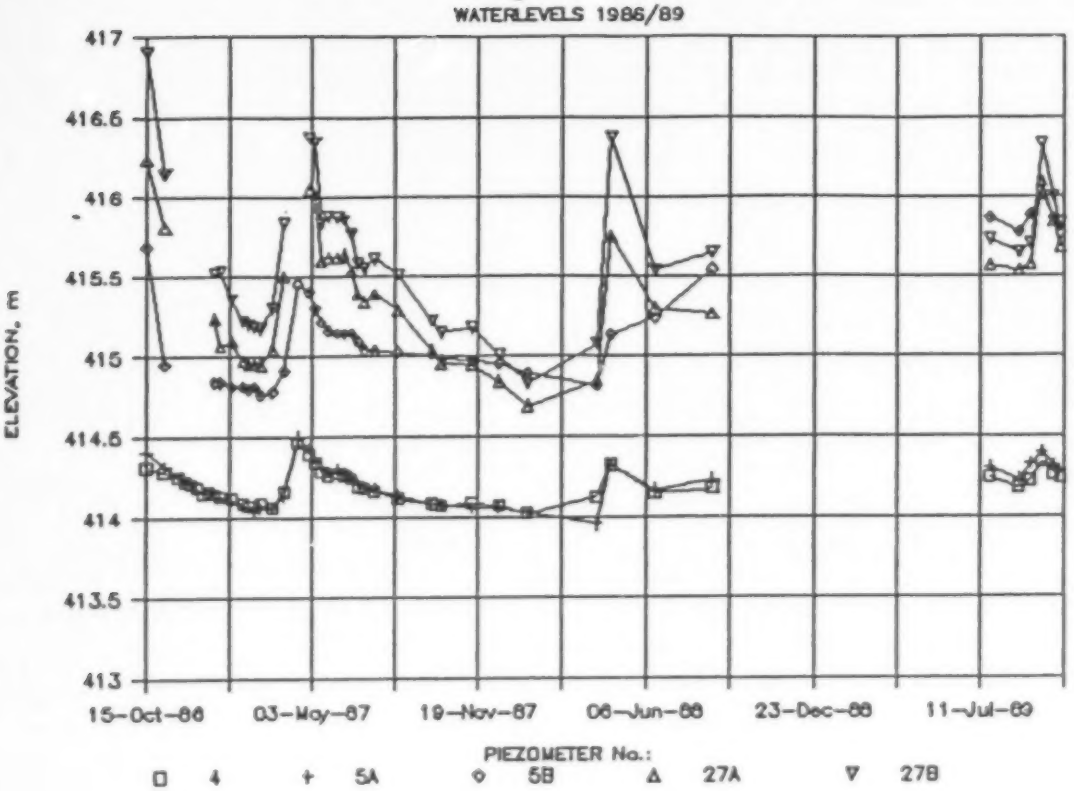
WATERLEVELS 1986/89
417
416.5
416
415.5
415
414.5
414
413.5
413
ELEVATION, m
15-Oct-86
03-May-87
19-Nov-87
06-Jun-88
23-Dec-88
11-Jul-89
PIEZOMETER No.:
4
5A
5B
27A
27B

Figure 5A

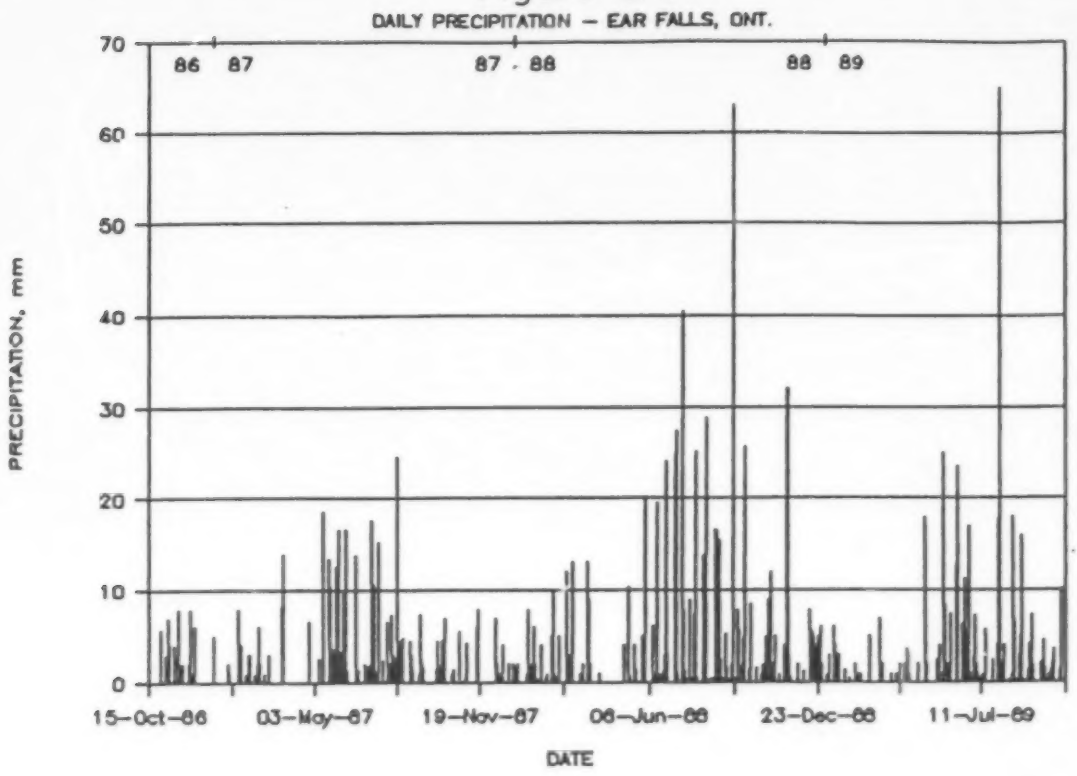

Figure 5B

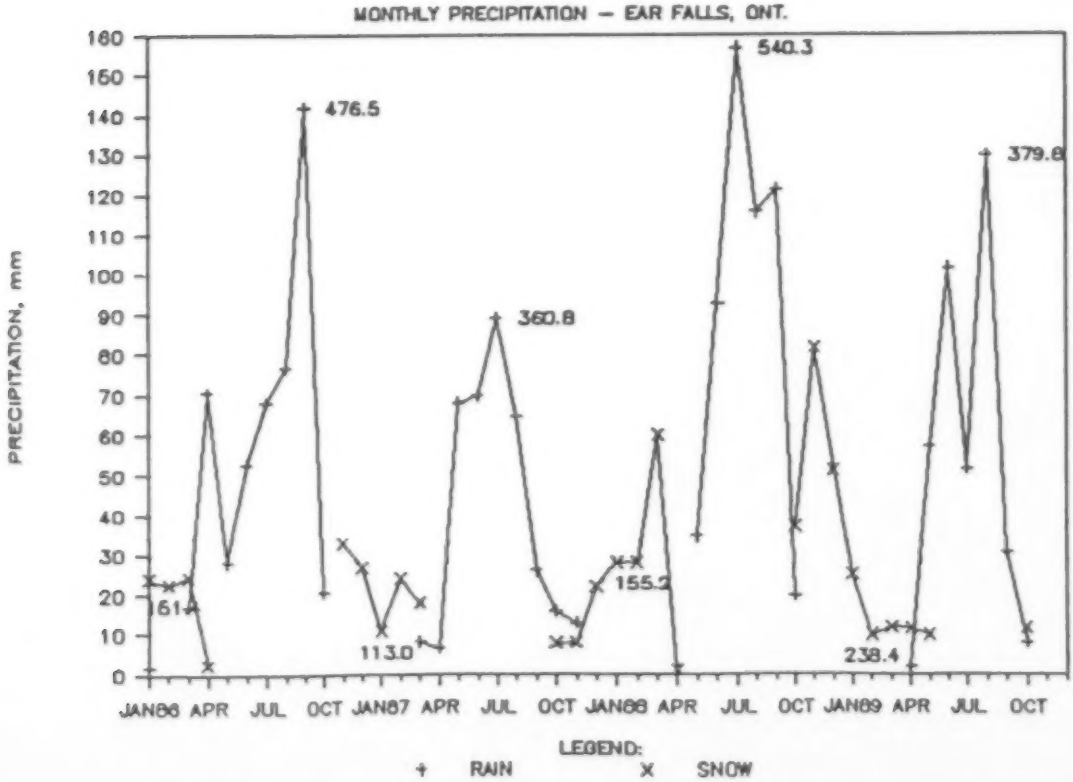

Figure 5C

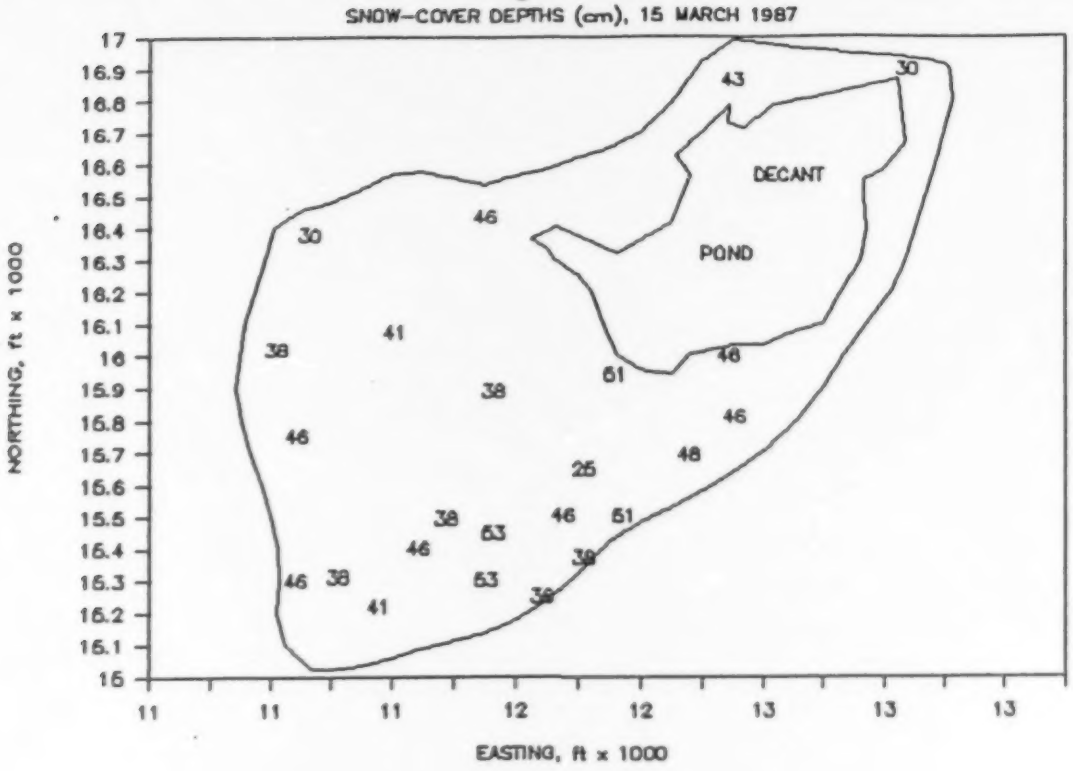

Figure 5D

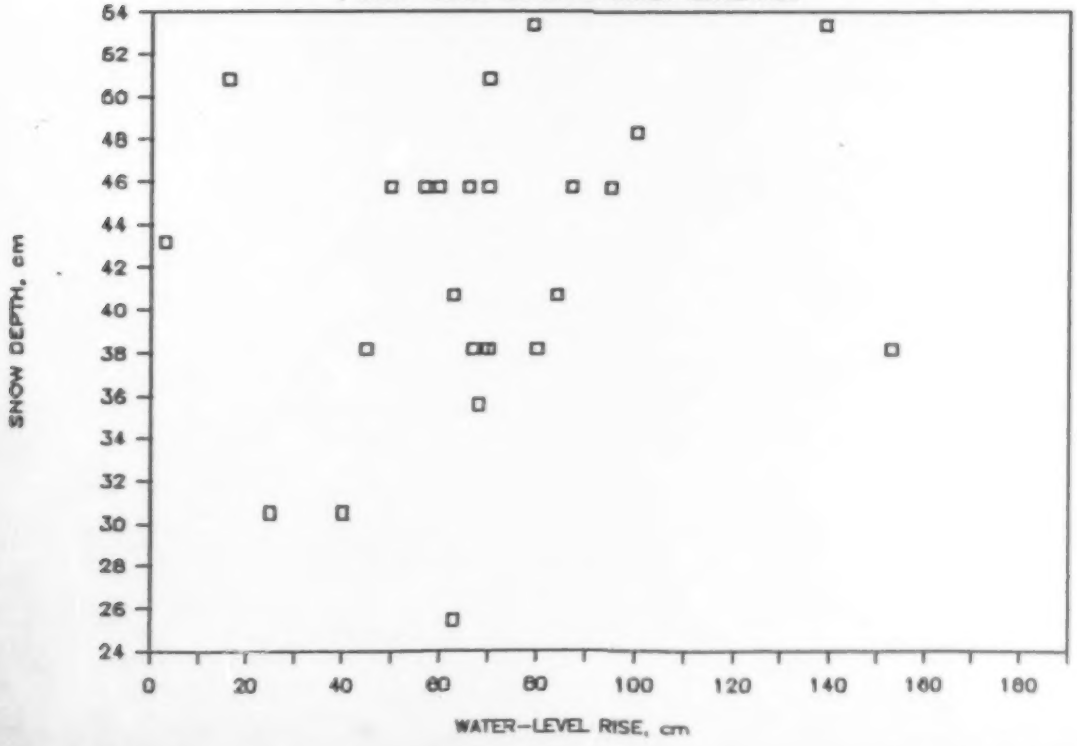

Figure 6A

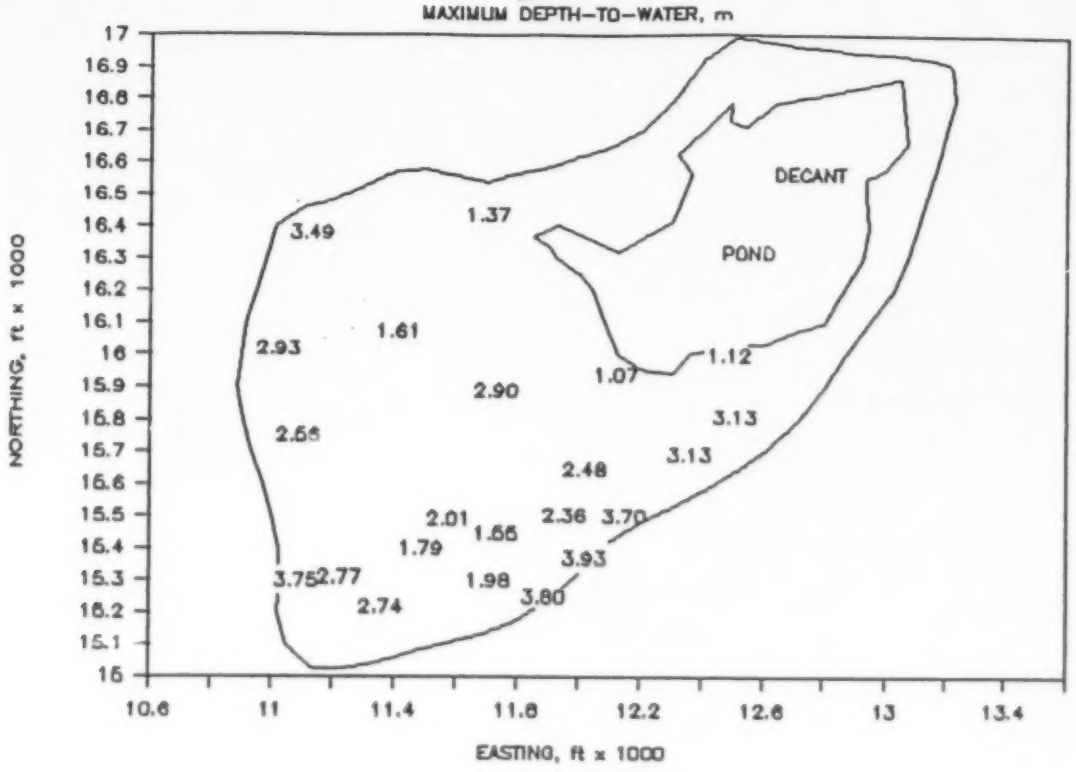

Figure 6B

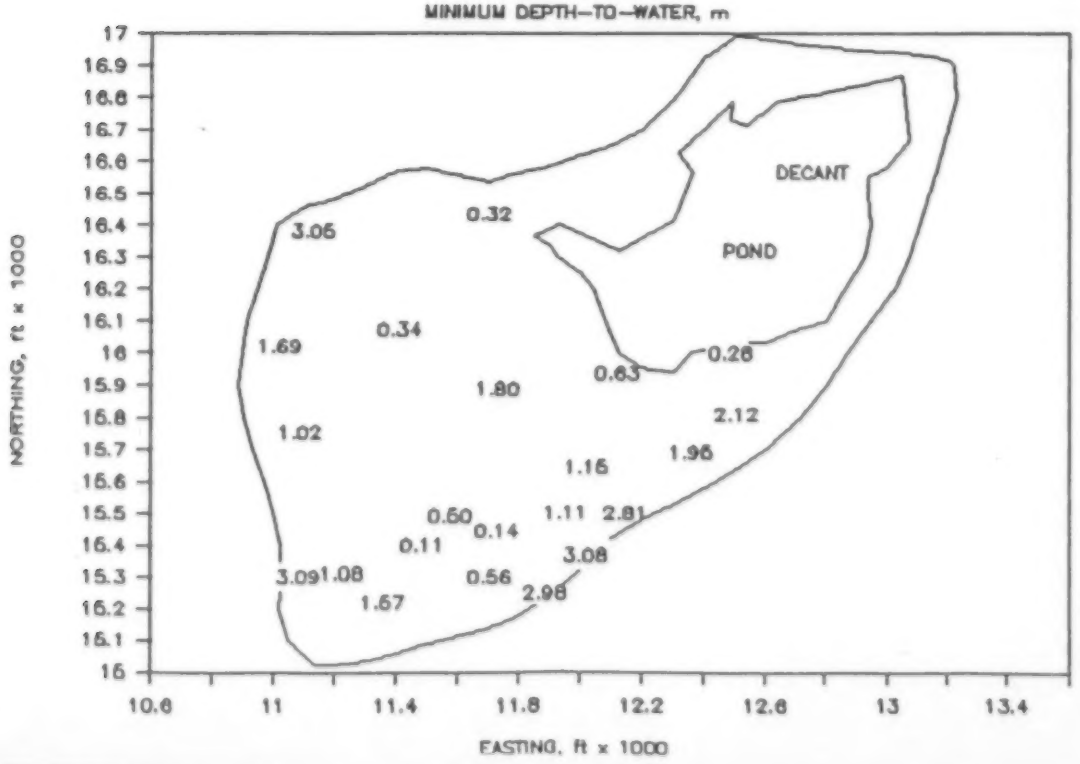

Figure 7A

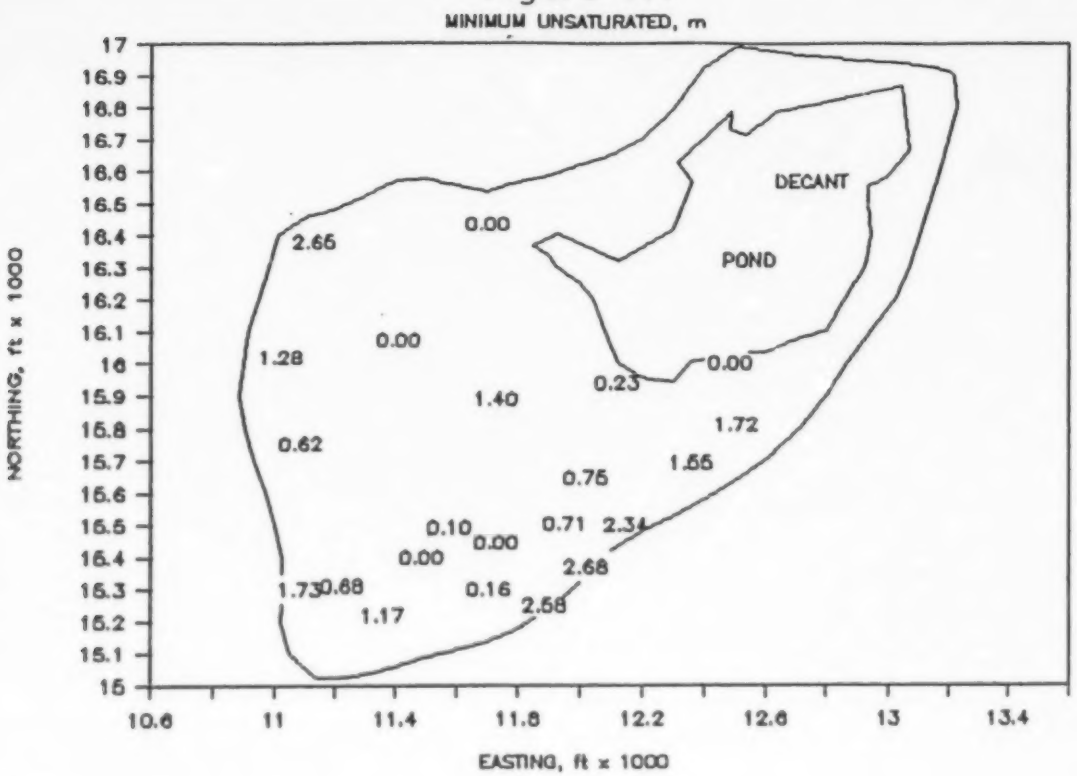

Figure 7B

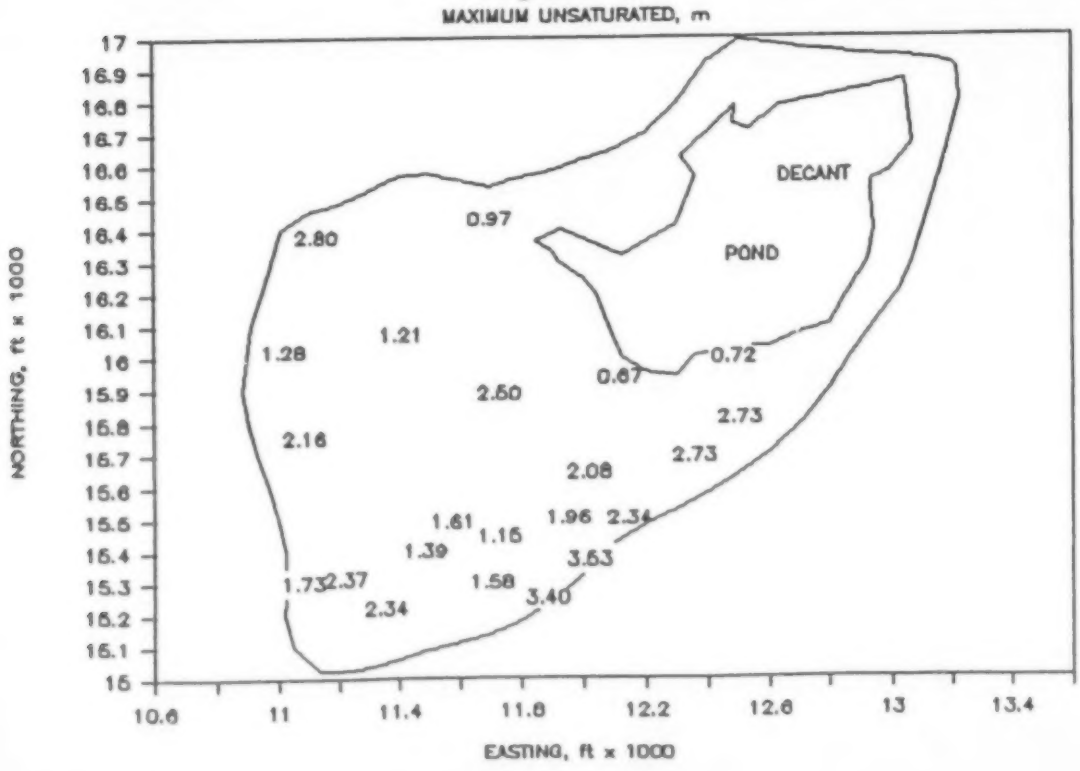

Figure 8A

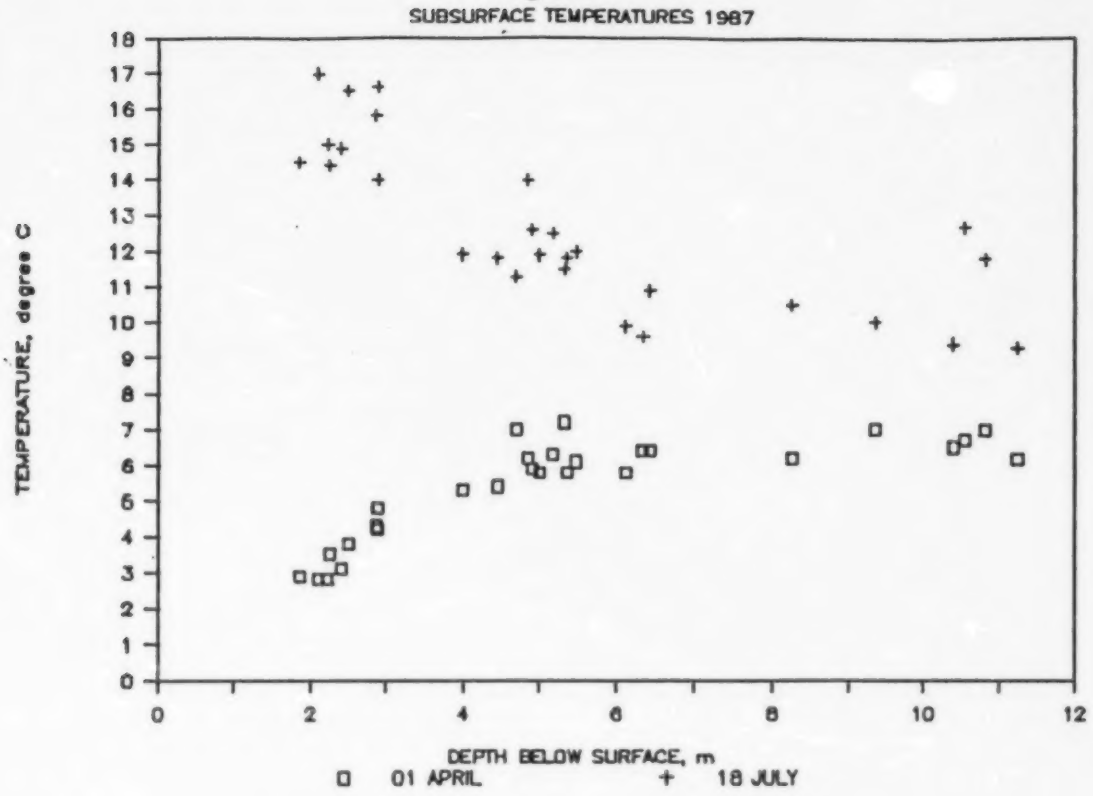

Figure 8B

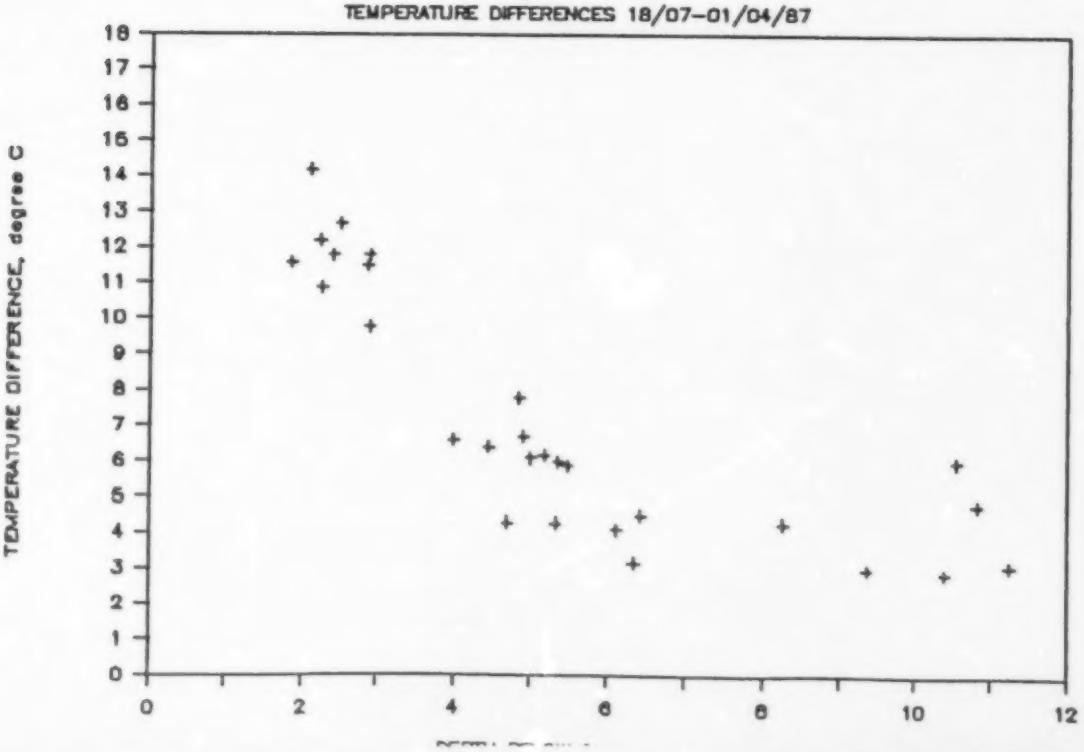

Figure 9A

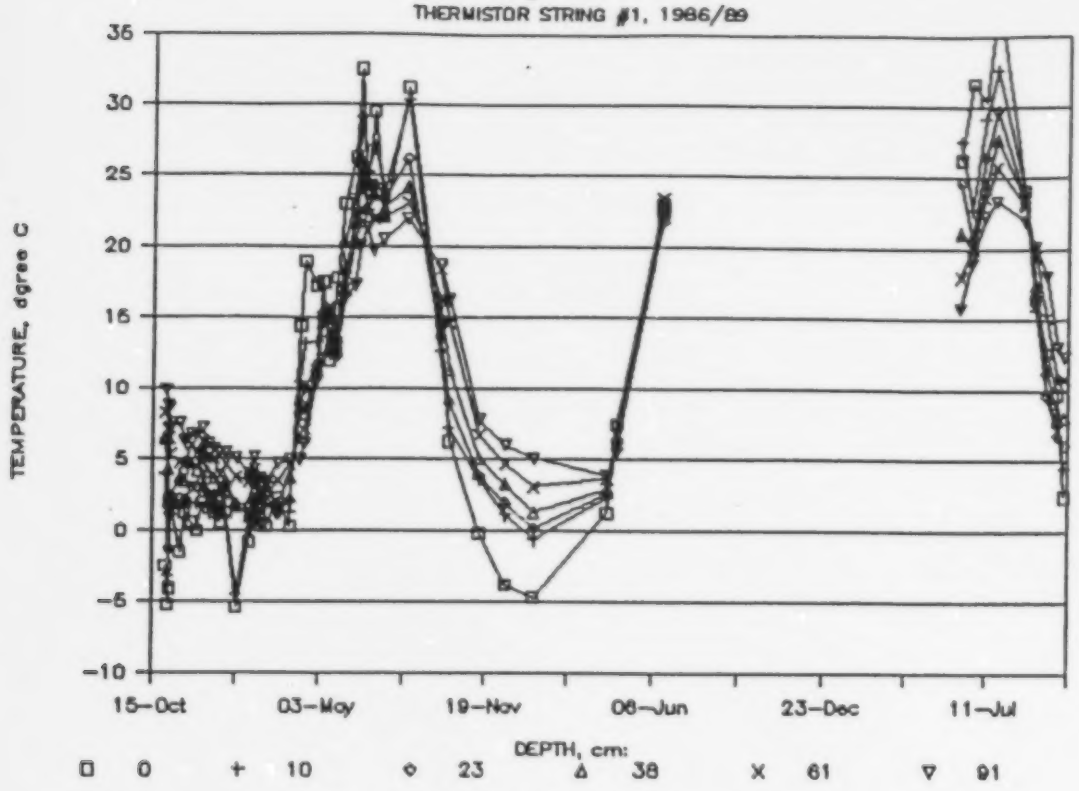

Figure 9B

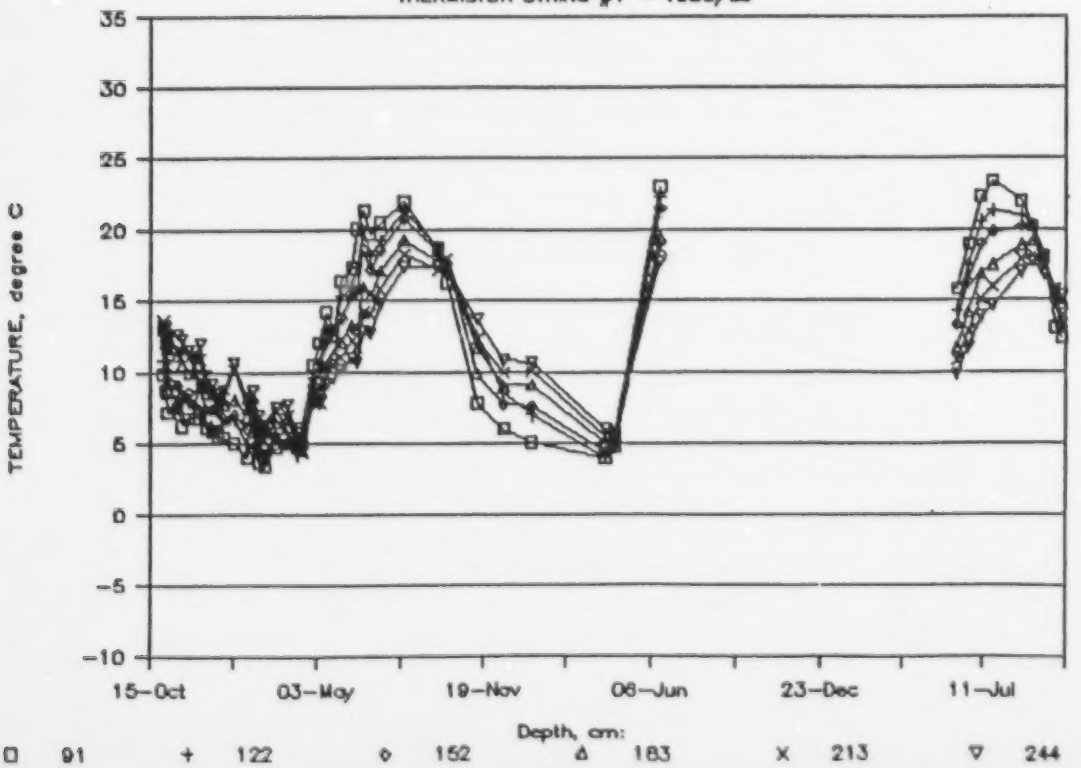

Figure 10A

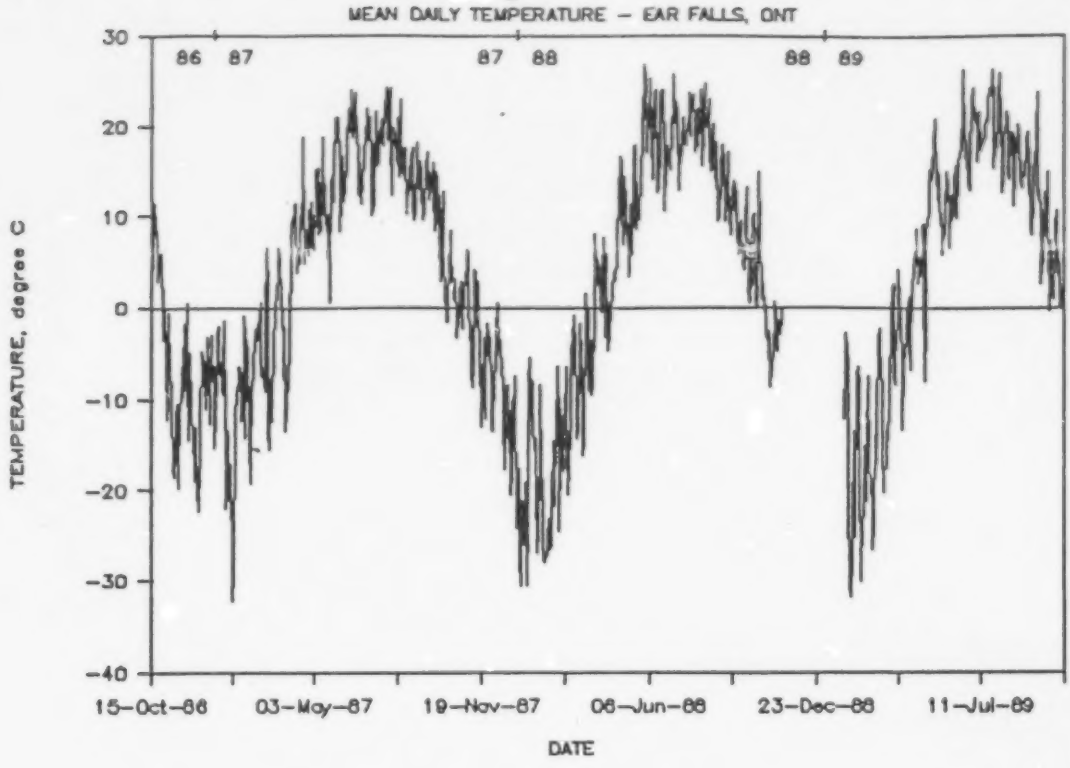

Figure 10B

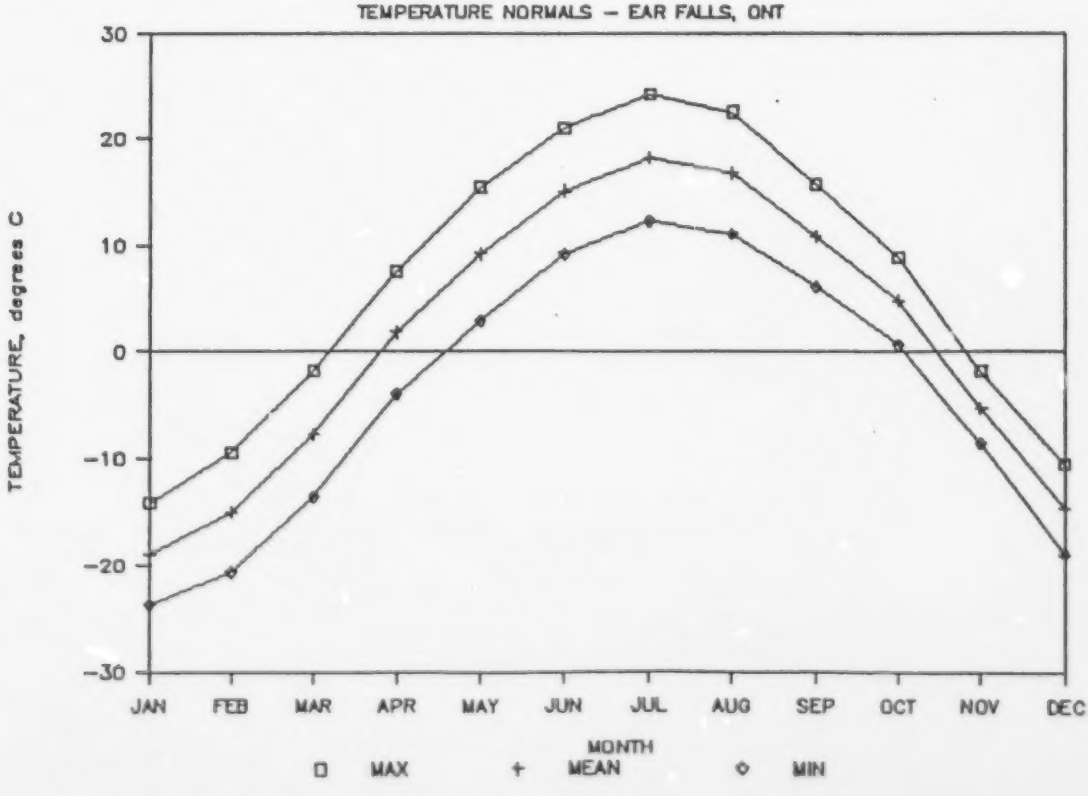

Figure 11A

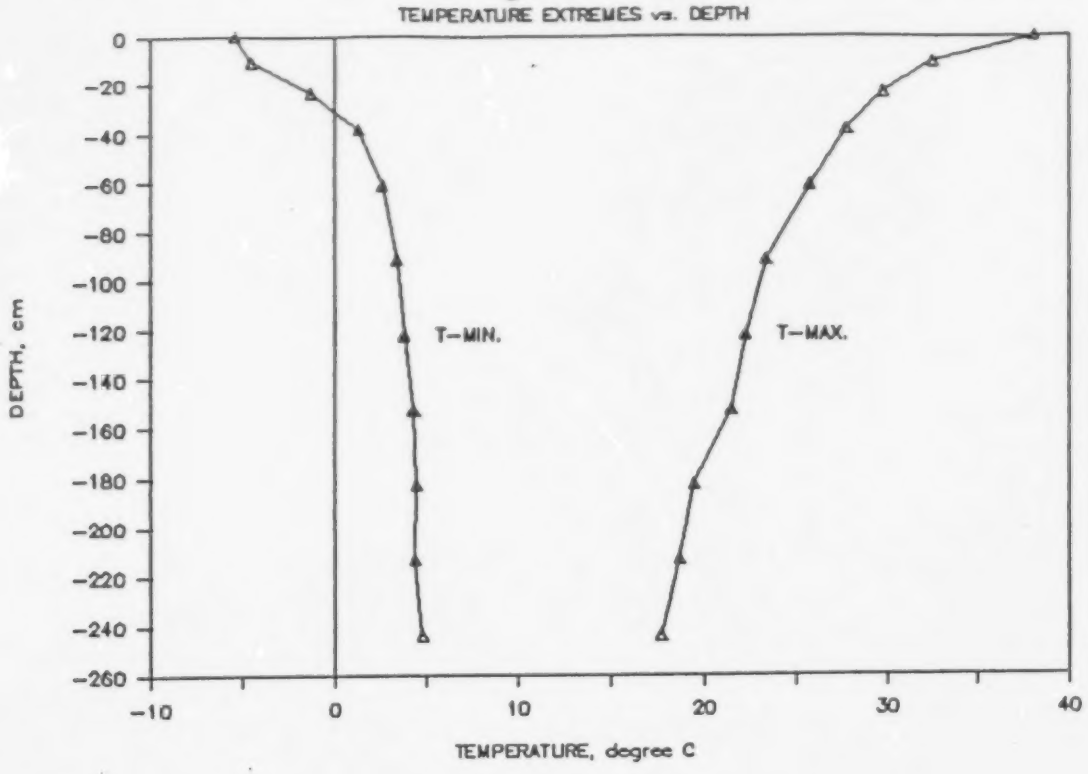

Figure 11B

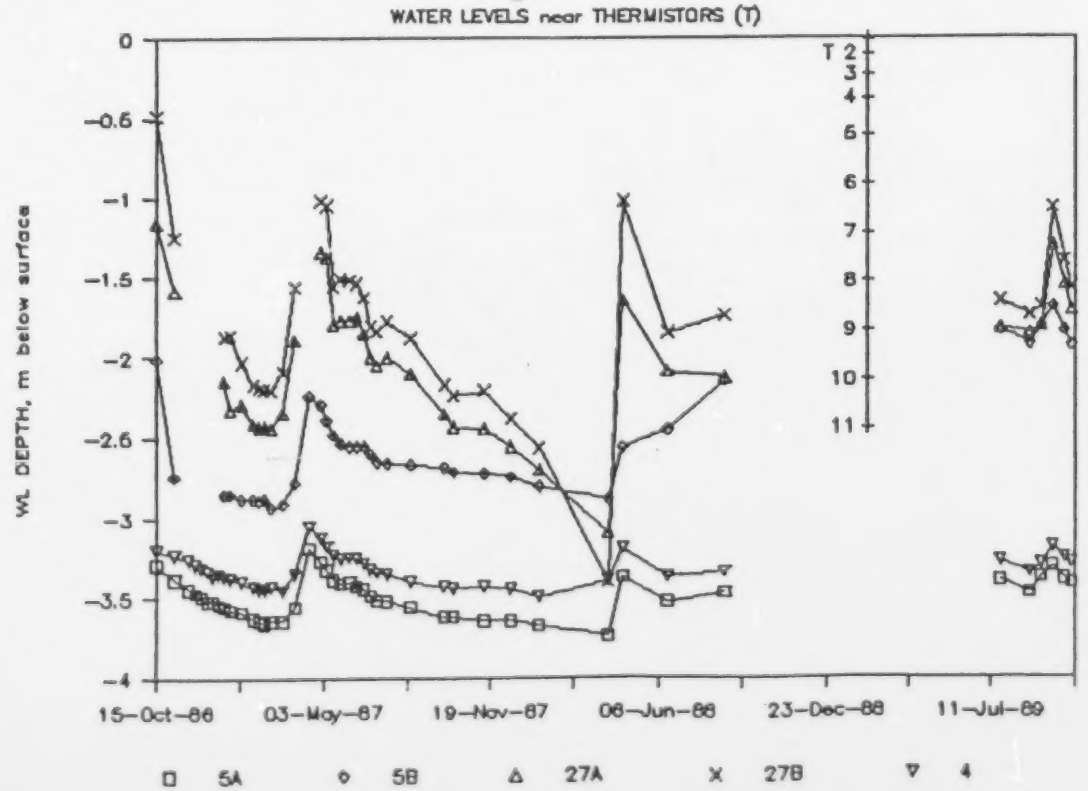

Figure 12A.

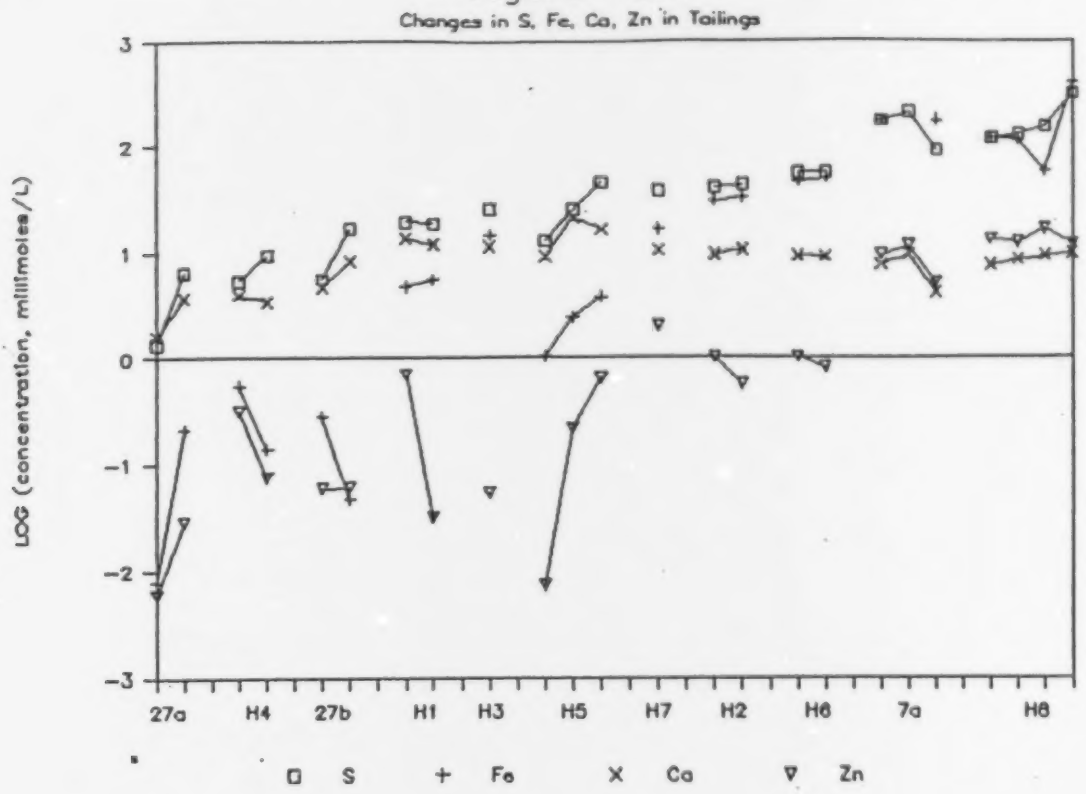

Figure 12B.

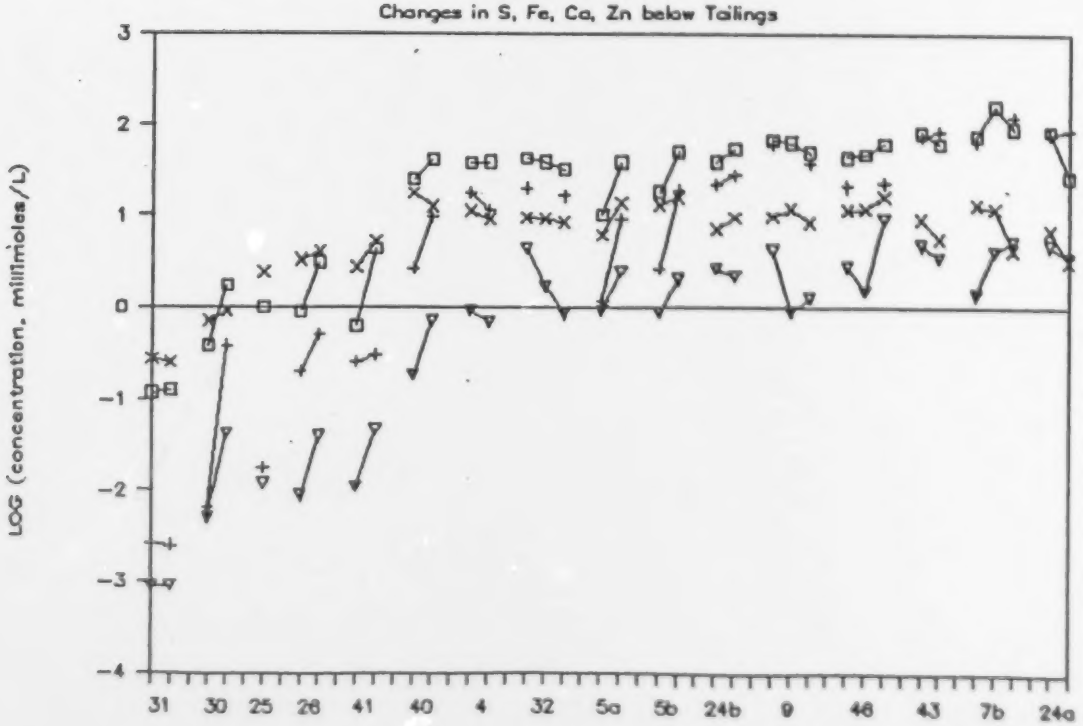

Figure 13A.

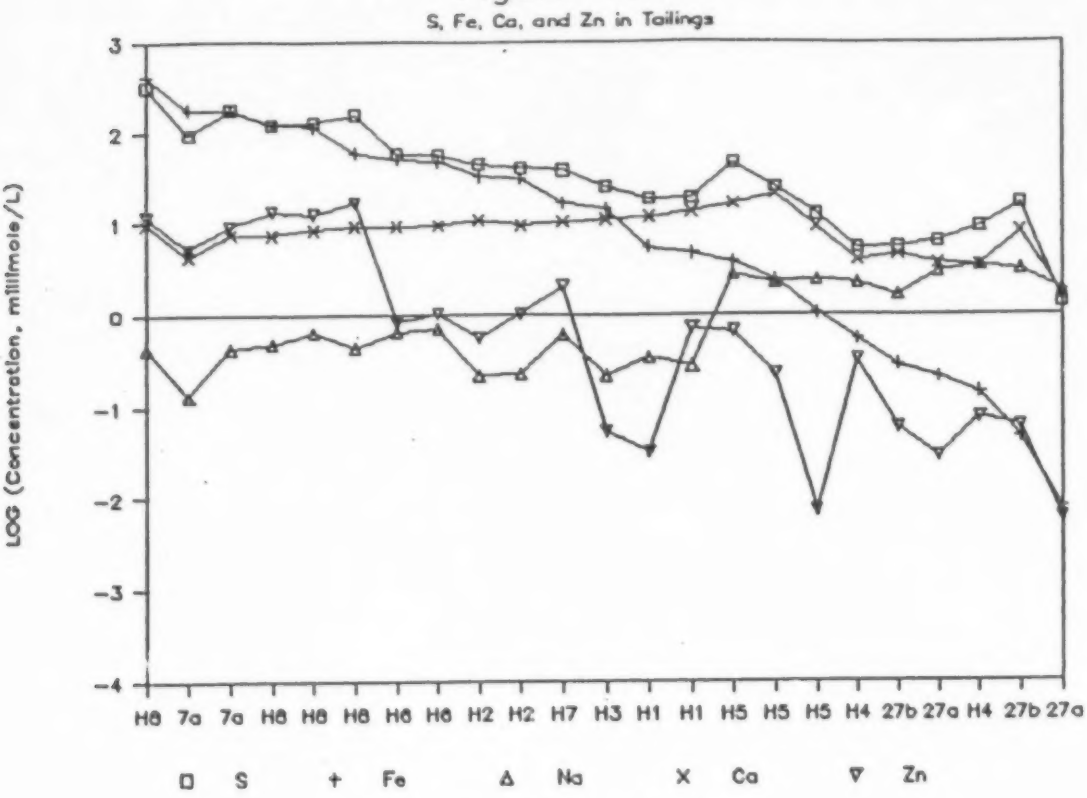

Figure 13B.

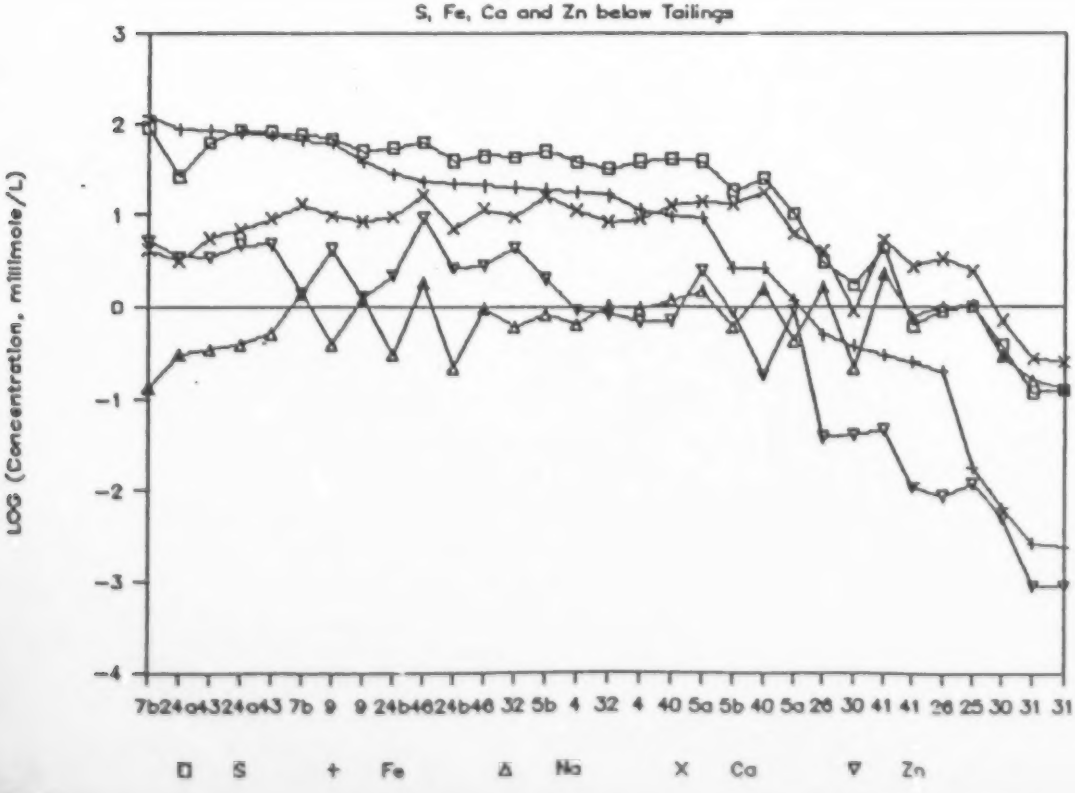

Figure 13C.

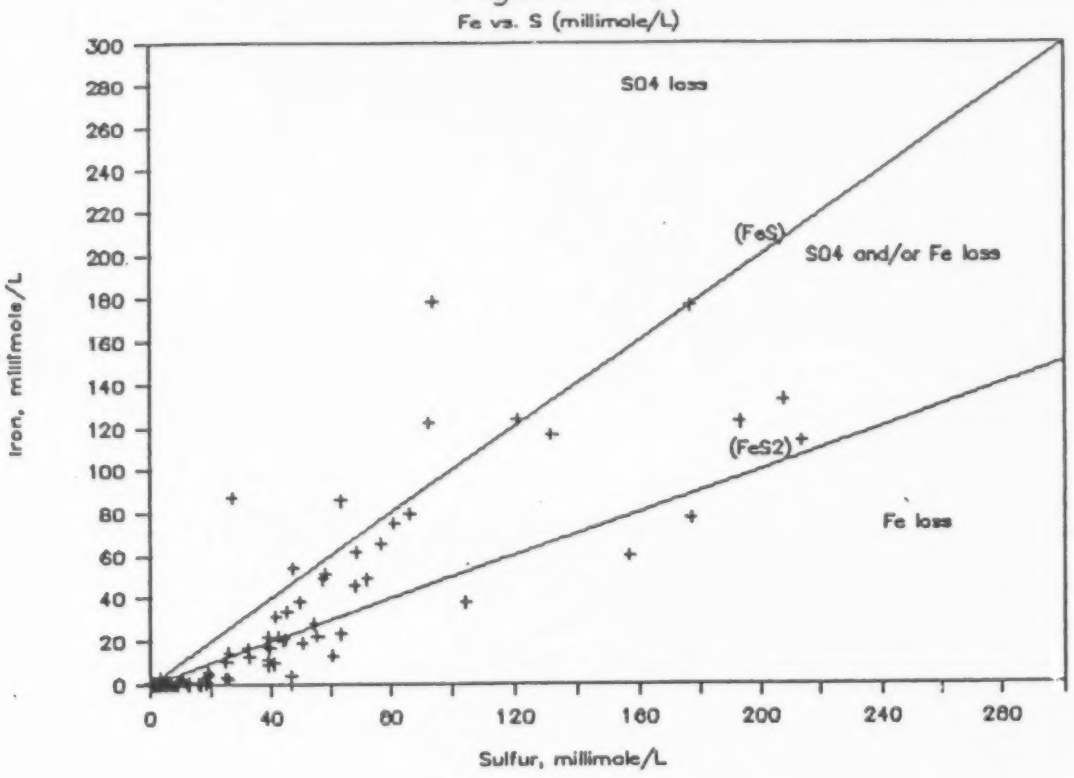
Fe vs. S (millimole/L)
SO4 loss
(FeS)
SO4 and/or Fe loss
(FeS2)
Fe loss
Iron, millimole/L
Sulfur, millimole/L
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
0
40
80
120
160
200
240
280

Figure 14A

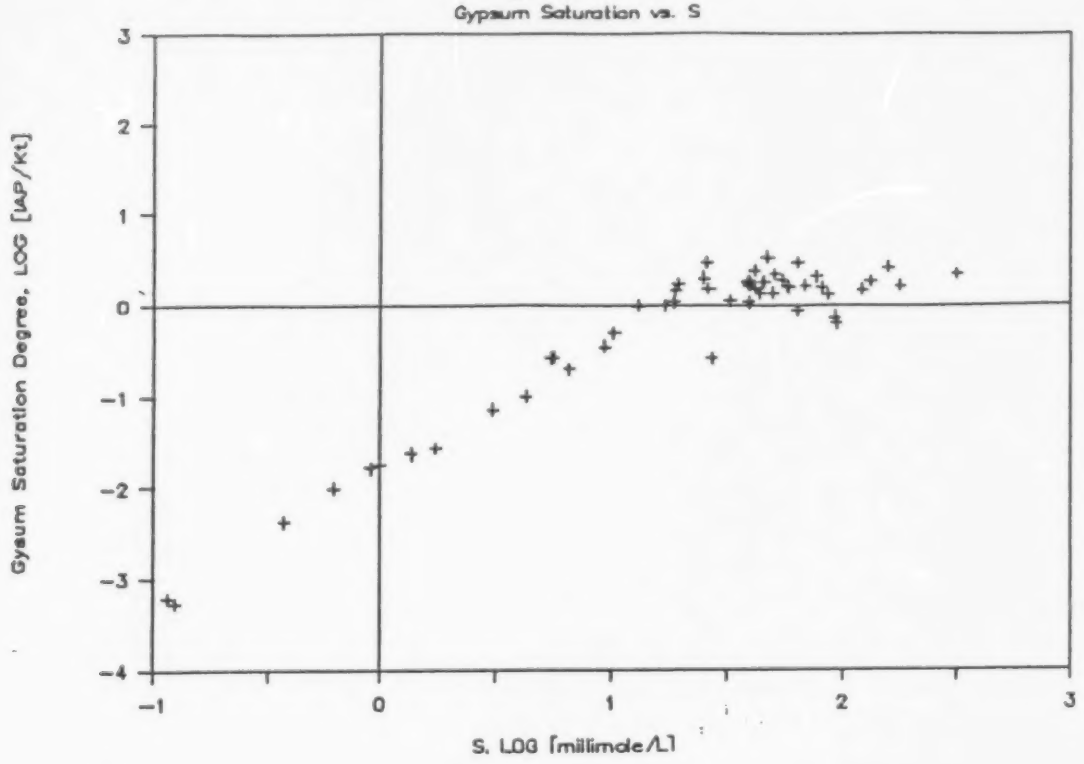

Figure 14B